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FUNCTIONAL DESCRIPTION AND GENERAL PERFORMANCE SPECIFICATIONS FOR THE WISCONSIN EXPERIMENT PACKAGE ORBITING ASTRONOMICAL OBSERVATORY A

by

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Prepared for

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SECTION I

INTRODUCTION

General

It is the purpose of this document to provide a detailed description of the Wisconsin Experiment Package (WEP), one of two major experiment equipments which will be mounted in a Grumman Aircraft Engineering Company Spacecraft and launched into a circular orbit as Orbiting Astronomical Observatory A (OAO-A). This document is aimed primarily at astronomers and other scientists who are interested in the experimental capabilities of the equipment, as well as to managerial, engineering and other personnel whose activities and interests bring them in contact with the WEP.

No attempt has been made herein to include data necessary for the engineer or technician interested in checking or repairing the WEP. For that purpose refer to the "Assembly and Disassembly Procedures for the Wisconsin Experiment Package".

The Wisconsin Experiment Package described herein was conceived by the Space Astronomy Laboratory of the University of Wisconsin, and was designed, developed and fabricated by the Tech-Center Division of Cook Electric Company, Morton Grove, Illinois, in cooperation with the Space Astronomy Laboratory and under contract No. NAS 5-1348, SUB. 1 from the University of Wisconsin.

Astronomical Objectives of the WEP

The primary objectives of the WEP are the determination of stellar energy distributions in the spectral region from 3300Å to 900Å, and the measurement of emission line intensities of diffuse nebulae in the same spectral band. Essentially all of the measurements of this type that have been made to date have been made via rocket sounding probes. These, at best, offer a very few measurements of short duration, from unstable platforms, and are perhaps of doubtful reliability. It is anticipated that the WEP will enjoy a substantial improvement in all of these areas.

The energy distribution of several thousand stars representative of the various types and of several emission nebulae will be examined. Multiple observations will be made on selected targets over a period of time to check observational consistency and the intrinsic variability of the energy distribution. By extending and broadening the base of our knowledge of stellar and nebular emission characteristics in the UV, valuable additional information of the composition of these bodies will be obtained. Similarly, the composition of the interstellar medium may be determined more fully by extending the opacity measurements of this medium into the UV.

Spacecraft Functions

The Orbiting Astronomical Observatories have been conceived as a series of interchangeable experiment packages carried in a standardized

Spacecraft. Fig. I-1 shows a phantom view of the Spacecraft with the Wisconsin Experiment Package installed. The Spacecraft provides several major functions essential to the operation of the experiment packages.

1. It provides equipment for communication with ground stations, so that experiment commands may be sent to the observatory and experiment measurement and other data may be sent back to the ground.

2. It provides storage for commands to be performed at some time after receipt of the command transmission, and also for storage of experiment measurement and related data until such time as it can be transmitted to a ground station.

3. It provides observatory orientation and pointing needs and supplies aiming angle data and certain other data needed by the experimenter to correlate with the WEP measurement and status data.

4. It provides primary experiment power (+28 vdc derived from solar batteries).

5. It provides for thermal regulation and control.

General Description of the Wisconsin Experiment Package

The complete WEP consists of two distinct and separate components, the Prime Instrument Package and the Control Electronics. See Fig. I-2. The former is a cylinder approximately 40 inches in diameter and 56 inches high, and is mounted in the upper half of the Spacecraft structural tube. It contains all of the optics, mechanisms, photodetectors, associated supporting structures and most of the electronics needed to make the actual photometric measurements. These are packaged into seven photometer modules: four Stellar Photometers covering various wavelength regions, one Nebular Photometer, and two Scanning Spectrometers. These modules are all mounted on the Primary Structure, which is a 40 inch diameter, I-beam-supported, honeycomb panel platform that provides the basic structural integrity of the Prime Instrument Package. This structure also contains interconnecting wiring, high voltage and 15 v dc-dc converters, energy storage capacitor banks, etc.

The Control Electronics is a rectangular package of approximately 7 x 12 x 23 inches, weighing about 40 lbs, and is located in equipment bay E-5 of the Spacecraft. The Control Electronics stores and decodes the experiment commands received from the ground via the Spacecraft command communication link. It then provides activation signals to the electronic, electromechanical, and optical devices located in the Prime Instrument Package.

The instrument data outputs are routed back to the Control Electronics package and formatted for readout to the Spacecraft Experimenters Data Handling Equipment. The programming of this data readout and selected Spacecraft data is normally controlled from within the WEP Control Electronics Package. The Control Electronics physically consists of 450 digital logic elements mounted on printed circuit boards.

About 200 of these elements are identical general purpose flip-flops consuming less than 4 milliwatts each.

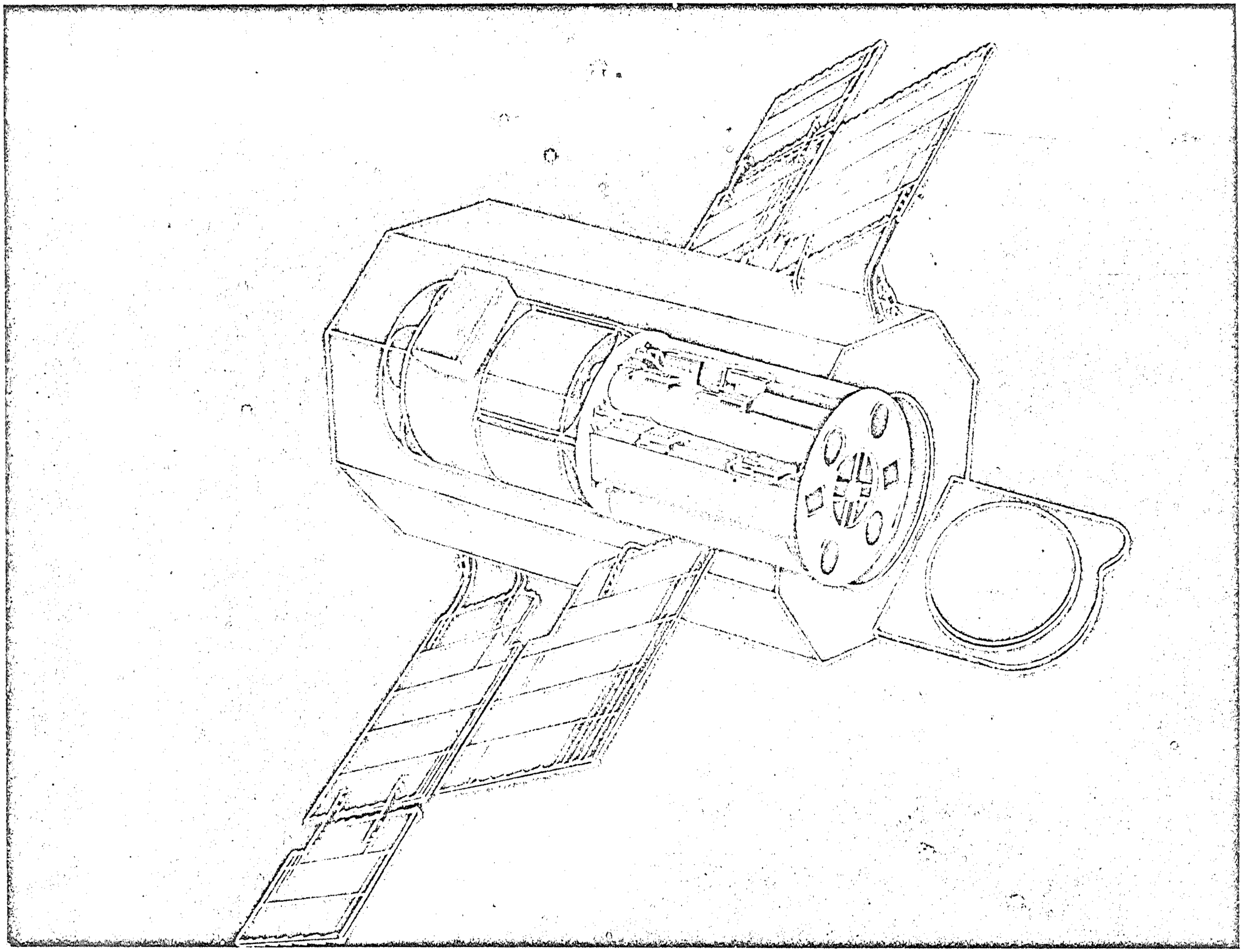


FIG. I-1 PHANTOM VIEW OF OAO SPACECRAFT SHOWING WISCONSIN EXPERIMENT PACKAGE INSTALLED

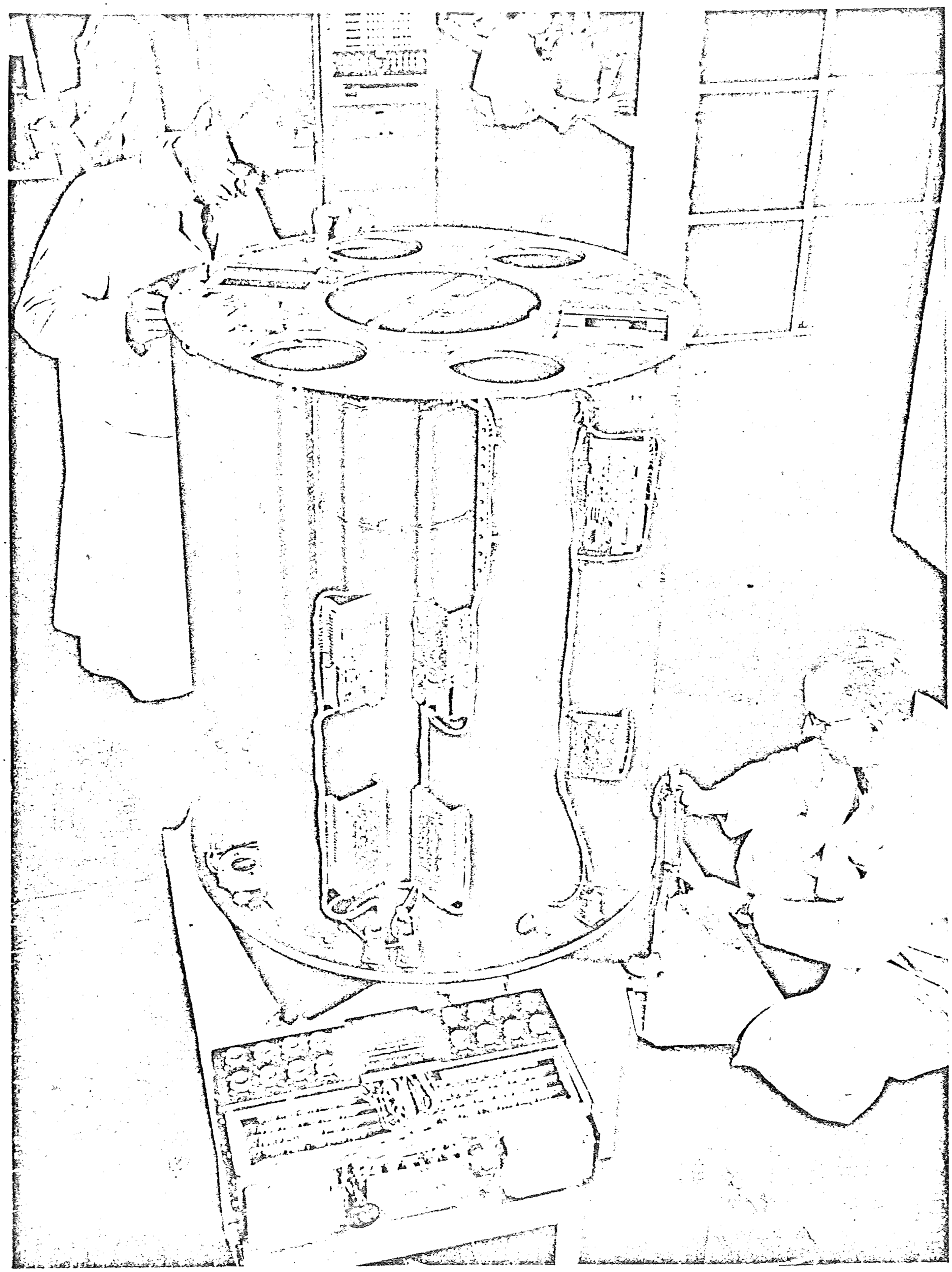


FIG. I-2 WISCONSIN EXPERIMENT PACKAGE
(DUST COVERS REMOVED)

SECTION II

STELLAR PHOTOMETER FUNCTIONAL DESCRIPTION

A. GENERAL

The functional block diagram of a stellar photometer is shown in Fig. II-1, a phantom view in Fig. II-2 and a photograph in Fig. II-3. These are applicable to all four Stellar Photometers.

The block diagram shows how the data output is obtained from the star source; what the controlling variables are in the optical-electronic path to data output; and how the command and timing inputs are used to initiate the control functions.

Star light is collected in a Herschelian-type telescope by an 8-inch diameter off-axis parabolic reflecting mirror having a 32 inch focal length. The collected light is passed successively through a field stop, an optical filter, and a field or Fabry lens to a photomultiplier tube. The pulse output of the detector tube is fed to an ac amplifier and pulse pre-counter chain, and the averaged output is fed to an integrating dc amplifier. The pre-counter output of the pulse counting chain is gated to a digital measurement counter for selected exposure times. Thus, stellar spectral intensity data outputs are available both as digital measurements for fixed time intervals, and as continuously integrated analog measurements.

The controlled variables in the optical-electronic path are field stop selection, re-collimation, filter selection, and exposure time and analog sensitivity selection. In general, the first two variables will be used only for corrective measures to compensate for misalignments caused by launch forces or spacecraft pointing errors. The other three variables are used for adjusting the spectral intensity sensitivity and wavelength selection, and for in-flight calibration. Experiment commands are delivered from Spacecraft storage at the desired execution time on Experimenter's Operation Code (EOC) lines. These, together with Bit Times and Clock Signals are appropriately gated, decoded and buffered to derive the signals used to control the variables in the optical-electronic path.

B. OPTICAL

A bevel around the perimeter of the off-axis paraboloid mirror limits the aperture of the system to 7-3/4 inches, yielding a total collecting area of 47.2 square inches (304 cm^2). This same diameter is repeated in the inside diameter of a structural ring at the opposite end of the tube so that a small amount of vignetting occurs for angles off the axis. At an angle of five minutes, which corresponds to the maximum observable field, the vignetting amounts to one per cent. Because of imperfect alignment between the end of the tube and the mirror one should expect a maximum total variation in incident flux of two per cent as a star moves across the ten minute field.

An enlarged view of the optical path in the vicinity of the prime focus is given in Fig. II-4. Located at this focus is a two position field stop providing viewing angles of two minutes and ten minutes of arc. The ten minute field is provided by a 0.093 inch diameter hole in the photomultiplier housing assembly. In general, this field stop will only be employed for special purposes, such as compensating for Spacecraft pointing errors, and to aid in in-flight recollimation, or perhaps special stellar or nebular observations.

A solenoid-actuated toggle action leaf is capable of sliding over the ten minute stop. Centered in this leaf is a small, 0.019 inch diameter aperture which defines the two minute field. The normal mode of operation will utilize this smaller stop.

The field stop assembly is capable of being translated laterally in the focal plane. This effectively changes the looking direction of the Stellar Photometer relative to the Spacecraft. Thus, post-launch re-collimation can be performed in the unlikely event that launching forces change the optical axis of a photometer. The field stops may be driven to a maximum ± 10 minute displacement in one minute increments along directions parallel to the Y_c and Z_c Spacecraft axes.

Located about one-half inch behind the field stop is a five-position filter wheel, Three of the positions are occupied by filters which generally are multiple layer interference filters evaporated on lithium fluoride or fused quartz substrates. A fourth position contains an opaque barrier (dark slide) while the fifth contains a calibration source.

The opaque barrier eliminates all incident radiation and permits measurement of the phototube dark current on zero signal condition. The calibration source consists of strontium-90 surrounded by a lucite ring covered with a quartz window which emits Cerenkov radiation. Similar calibration sources are used in all four photometers.

The filter characteristics for each photometer are tabulated in Fig. II-5. Examination of these data reveals that, starting with Stellar Photometer No. 1, each unit contains a filter in common with the next succeeding one. It is also seen that No. 1 responds to the longest wave-length radiation, in fact, extending into the visible violet, and each succeeding unit, in general, covers successively shorter wavelengths. This arrangement permits the very useful function of in-orbit relative recalibration of all photometers. The signal output of Photometer No. 1 using its filter No. 1 and viewing a given star can be correlated with an absolute measurement of the same star made from the earth. Then Photometer No. 2 can be compared with No. 1 through their common filter, and so on for all units. In this way, calibration can be periodically verified during the one-year lifetime of the satellite. Furthermore, duplication of filters provides redundancy in case of failure of one of the units.

Following the filter wheel, a field lens (Fabry lens) is located in all photometers except No. 4. The design characteristics of this lens vary for each photometer and are tabulated in Fig. II-6. Its function is to immobilize the spot of radiation incident on the photomultiplier regardless of the motion of the stellar image in the field stop. In this way, over-all system response is held constant in spite of point-to-point variations in sensitivity of the photocathode surface.

This type of lens is not used in Photometer No. 4 because originally it was planned to extend the response of that unit to wavelengths shorter than the cutoff of all known refractive materials. Therefore, it may be expected that the response of Photometer No. 4 will vary somewhat depending upon the position of the stellar target in its field of view.

C. ELECTRONICS

1. Field Stop Selection

For the stellars, one of two field stop apertures may be selected providing viewing angles of 2 and 10 minutes of arc. The normal mode of operation is with the small field stop.

The field stop mechanism is a two position device (see Fig. II-7) operated by a solenoid. The solenoid in turn is controlled by gating appropriate Command Code lines and a Bit Time signal (see Fig. II-8). The output of the gate is buffered with an emitter follower, and subsequently used to trigger a monostable multivibrator. The stretched pulse monostable output feeds a drive amplifier which is used to operate the solenoid. The mechanism is such that each solenoid actuation changes the field stop aperture. A two-position commutator is used to detect whether the small or large field stop is in the optical path and to provide this information as part of the digital status output data.

2. Re-collimation

An in-flight re-collimation capability is available for minor realignment which may be required as a result of shifting of the Stellar Photometer pointing axis relative to the Spacecraft pointing axis due to launch forces, etc. Re-collimation is accomplished by moving the field stop aperture in the focal plane. The aperture may be moved in 1 arc minute increments over a $\pm$ 10 minute range along each of two orthogonal axes in the focal plane (see Fig. II-4).

The re-collimation is controlled by two bi-directional stepping motors, one for each axis, whose shafts are linked to the field stop aperture positioning arm. These motors are controlled in a similar manner to that of the aperture mechanism. The AND gate output of the proper input Command Code and Bit Time signal is again buffered and triggers a monostable. The monostable output feeds a drive amplifier which is used to step one of the motors in one direction. Thus, each transmission of the command causes one added step to be taken in a selected direction. Separate but identical channels are provided for each drive direction on each axis of alignment. Digital status data obtained from parallel switches provide an indication when <u>either</u> collimation mechanism has reached its limit of travel in one particular direction on its axis. It should be noted that only one bit of digital output status data is available for this purpose for each photometer, and this bit must therefore serve both re-collimation axes of that photometer.

3. <u>Filter Wheel</u>

The filter wheel position control is accomplished by means of a digital servo loop. A logic diagram for this operation is shown in Fig. II-9. Commands are read into a control register by AND gating appropriate sets of Bit Time lines with one of the appropriate input EOC Command Code lines. The control register for the filter wheel position command is a set of parallel in, parallel out, memory flip flops. The flip flops first reset at the beginning of the entry of a new command by the

AND gate amplified output from Bit Time Line 3 and the proper EOC line, and then set according to the code of that command. Decoding of the command input is accomplished by AND gating the combinations of the flip-flop outputs with a feedback line from a commutator on the filter wheel shaft. An output from any of the AND gates is inverted and prevents the 1 pps Clock Signal from causing the filter wheel drive stepping motor to step to a new position. Consequently when a new command is entered into the control register, the filter wheel will be stepped unidirectionally one filter position per step at a one step per second rate until the position agrees with the Command Code input. The feedback signal from the commutator is encoded in binary form and inverted to provide filter wheel position signals as part of the digital status output data. Redundant input Command Codes and complementary Bit Time signals are used in the filter wheel position control to provide a higher degree of reliability.

4. Data Measurements Circuitry

The functional block diagram of the data measurement circuitry is shown in Fig. II-10. This diagram is divided into three parts for discussion purposes; (a) photomultiplier assembly, (b) pulse measurement circuitry, and (c) analog measurement circuitry.

(a) Photomultiplier Assembly

The photomultiplier assembly consists of the photomultiplier tube and a transistorized pulse pre-amplifier. Two types of PM tubes are used in the stellar photometers: EMI 6256B for Stellars 1 and 2, and ASCOP 541F for the shorter wavelengths of Stellars 3 and 4. Figure II-11 shows a comparison of the pertinent characteristics of the two tubes. The operating potentials chosen are -2300 volts for the ASCOP and -1200 volts for the EMI.

A photoelectron emitted from the photocathode of the PM tube produces an amplified output pulse at the anode by the electron multiplication process of the tube. This pulse is further amplified by the pre-amplifier and presented to the pulse amplifier and discriminator. The pulse at the anode is also integrated and presented to the analog amplifier.

The pulse pre-amplifier is a potted assembly of three transistors and associated components mounted on a printed circuit board attached to the rear of the PM tube (socket or assembly). One of the three transistors is connected as a gain stage, while the other two are connected as emitter followers and provide input and output isolation and impedance matching. The pre-amplifier is ac coupled to the anode of the PM tube and provides amplified pulses at a low output impedance which are transmitted over a coaxial cable to the remotely located pulse amplifiers and discriminator circuits. The printed circuit board also contains the ac-dc isolation circuit and initial integrating components for the dc integrating (analog) amplifier.

(b) Pulse Measurement Circuitry

The pulse measurement circuitry contains a high speed pulse conditioner, a high speed pre-counter, and a low speed measurement counter with means of controlling exposure time. The pulse conditioner and pre-counter are assembled from transistorized welded logic elements and are located on an amplifier chassis on the associated Stellar Module structural tube. The measurement counter and exposure control circuits are also assembled from transistorized welded logic elements but are located in the Control Electronics package mounted in Bay E-5 of the Spacecraft.

The pulse conditioner consists of two pulse amplifiers, a Schmitt trigger discriminator circuit and a counter drive amplifier. The pre-counter consists of three high speed and three medium speed flip-flops and an emitter follower line driver.

The signal pulses from the pulse pre-amplifier are further amplified by the pulse amplifiers to a level sufficient to exceed the threshold of the Schmitt trigger discriminator. The discriminator is used to differentiate between PM tube and circuit noise and the signal pulses. It also serves as a drive amplifier to shape and invert the signal pulses for the pre-counter.

The square wave signal pulses from the counter drive amplifier are counted down in a serial binary fashion by a factor of 64 in the pre-counter. The pre-counter is used to increase the statistical accuracy of the measurement, and this function is covered more fully in Section V. The output of the last binary countdown stage of the pre-counter is buffered with an emitter follower which drives the coaxial line to the measurement counter AND gate in the Control Electronics. The pre-amplifier and pulse measurement circuits have an over-all pulse resolution of about 0.5 microseconds.

The measurement counter consists of an eight bit serial in, parallel out binary counter, a diode AND gate to control the entry of pulses into the counter, an exposure time generator, and a time delay circuit. The exposure time generator is made up of various gates and binary countdown circuits to generate the time control for gating the measurement signal pulses, as well as to generate buffered control signals for selecting the analog amplifier sensitivity range. Referring to Figs. II-1 and II-10, the control of the generator is accomplished by use of Exposure Time Commands and a delayed Start Exposure Command, plus Clock Signals of 1 pps and 1042 pps. Four Exposure Time Commands are utilized: 1/8, 1, 8, and 64 Spacecraft seconds.

The Exposure Time Command acts as a limit on the exposure time countdown of clock pulses following a delayed Start Exposure Command. The 1/8 second exposure time is determined by a binary countdown of 128 pulses of the 1042 pps Spacecraft Clock Signals. The 1, 8, and 64 second exposure times are determined by an appropriate binary countdown of the 1 pps Spacecraft Clock Signal. The countdown is initiated by a Start Exposure Command which is time delayed from the entry of each new command to allow for the maximum required filter wheel positioning time.

Using the 1/8 second exposure, the pulse measurement circuitry can count without dumping (filling the counter beyond its storage capacity) signals having an average rate of 131K pps at the PM anode. Average rates up to 1.0 M pps can be measured, using analog-digital correlation to determine the number of dumps. However, the 0.5 micro-second pulse resolution limit results in a (predictable) non-linearity in this region. Using the 64 second exposure, pulse rates as low as 2 pps can be counted with significance.

c. Analog Measurement Circuitry

The analog measurement circuitry is composed of a dc operational amplifier with relay controlled sensitivity ranges. The amplifier and latching type relays are mounted on two printed circuit boards located on an amplifier chassis on the Stellar Module structural tube. The operational amplifier has a balanced electrometer tube pair input stage followed by a transistorized amplifier. The selectable sensitivity ranges are 10^{-6}, 10^{-7}, 10^{-8}, and 10^{-9} amperes full scale and directly correspond to 1/8, 1, 8, and 64 second exposure times used in the pulse measurement circuitry. Upon receipt of one of the four Exposure Time Commands the exposure time generator sends a signal to the analog amplifier gain control relay drive to set up the appropriate sensitivity. As this amplifier is utilized for integrating, specific time constants are provided for the various ranges. In each case these are 1/4 of the associated exposure time: 1/32, 1/4, 2, and 16 seconds.

Input pulses from the photomultiplier assembly will cause an averaged dc input current to flow into the grid of one electrometer tube, in turn causing the plates of the two tubes to unbalance. This unbalance is amplified by the transistor amplifier causing its output voltage to rise, which in turn, feeds a current back through the selected feedback resistor. The output voltage will increase until the current through the feedback resistor equalizes the average input current at the grid, at which time the output voltage will remain constant. The rate of change of the output voltage is dependent upon the RC time constant across the amplifier.

The analog measurement voltage is directed to the Spacecraft analog-to-digital converter, where, upon command, it is converted to an 8-bit digital signal for storage and transmission. The full scale output voltage range usable by the Spacecraft is from 0 to + 5.06 volts. The linear range of the amplifier itself is larger than this, but is clamped between about + 7.0 and -0.2 volts to protect the Spacecraft A-D-C. The output voltage, with zero input current, is offset by approximately +0.150 volts so that small signals would not be lost if the amplifier zero were to drift negatively during the long orbital life of the equipment.

D. SUMMARY OF ALL OUTPUT DATA AVAILABLE FROM THE STELLAR PHOTOMETERS

By way of a summary, and for ease of understanding, all output data which is obtained from each Stellar Photometer is reviewed below. All WEP digital output data is formatted into four 25-bit words as shown in Fig. VII-3. All Stellar No. 1 digital data, with the exception of collimation limit status, is contained in digital output word No. 1 (along with data from other sources). Similarly, the digital data from Stellars Nos. 2, 3, and 4 are contained in digital output words Nos. 2, 3, and 4, respectively.

Stellar data may be conveniently divided into two classes: photometric measurement data, and status data.

1. Photometric Measurement Data

(a) Digital Photometric Measurement Data

This consists of an eight-bit measurement (full scale: 2^8 = 256 units), occupying bit positions 4 through 11 in the appropriate digital output word, and with bit position 4 containing the least significant bit.

(b) Analog Photometric Data

The analog photometric measurement has an output voltage range of from 0 to + 5.06 volts, and this is ultimately digitized in the Spacecraft for subsequent telemetry into 2^8 (= 256) units, for a .0198 volt unit of resolution. The table below shows, for each of the four analog sensitivity ranges, the averaged dc PM anode current required for full scale and for one unit of resolution. The sensitivity ranges are expressed in terms of the corresponding digital exposure.

Sensitivity Range	Full Scale Amps	Unit of Resolution Amps
1/8 second exposure	10^{-6}	3.9×10^{-9}
1 second exposure	10^{-7}	3.9×10^{-10}
8 second exposure	10^{-8}	3.9×10^{-11}
64 second exposure	10^{-9}	3.9×10^{-12}

2. Status Data

(a) Filter Wheel Position Status

This information is presented, in binary coded form, in bit positions 12, 13, and 14 of the corresponding digital output word (i.e., word 1 for Stellar 1, etc.).

Filter Wheel Position	Word Bit Positions 12	13	14
1	0	1	1
2	1	0	1
3	0	0	1
4	1	1	0
5	0	1	0

(b) Exposure Time Status

This information is presented in bit positions 15 and 16 of the corresponding digital output word.

Exposure Time	Word Bit Positions 15	16
1/8 second	1	1
1 second	0	1
8 seconds	1	0
64 seconds	0	0

(c) Aperture (Field Stop) Position Status

This information is presented in bit position 17 of the corresponding digital output word.

Aperture Position (Field Size)	Word Bit Position 17
2 arc minutes	1
10 arc minutes	0

(d) Collimation Limit Status

For all four stellar photometers, this data is presented in digital output word 4, bit positions 18 through 21 as follows:

Stellar No.	1	2	3	4
Bit Position	18	19	20	21
Limit Location	$-Y_c$, $+Z_c$	$+Y_c$, $+Z_c$	$+Y_c$, $-Z_c$	$-Y_c$, $-Z_c$
Not at Limit	1	1	1	1
At Limit(s)	0	0	0	0

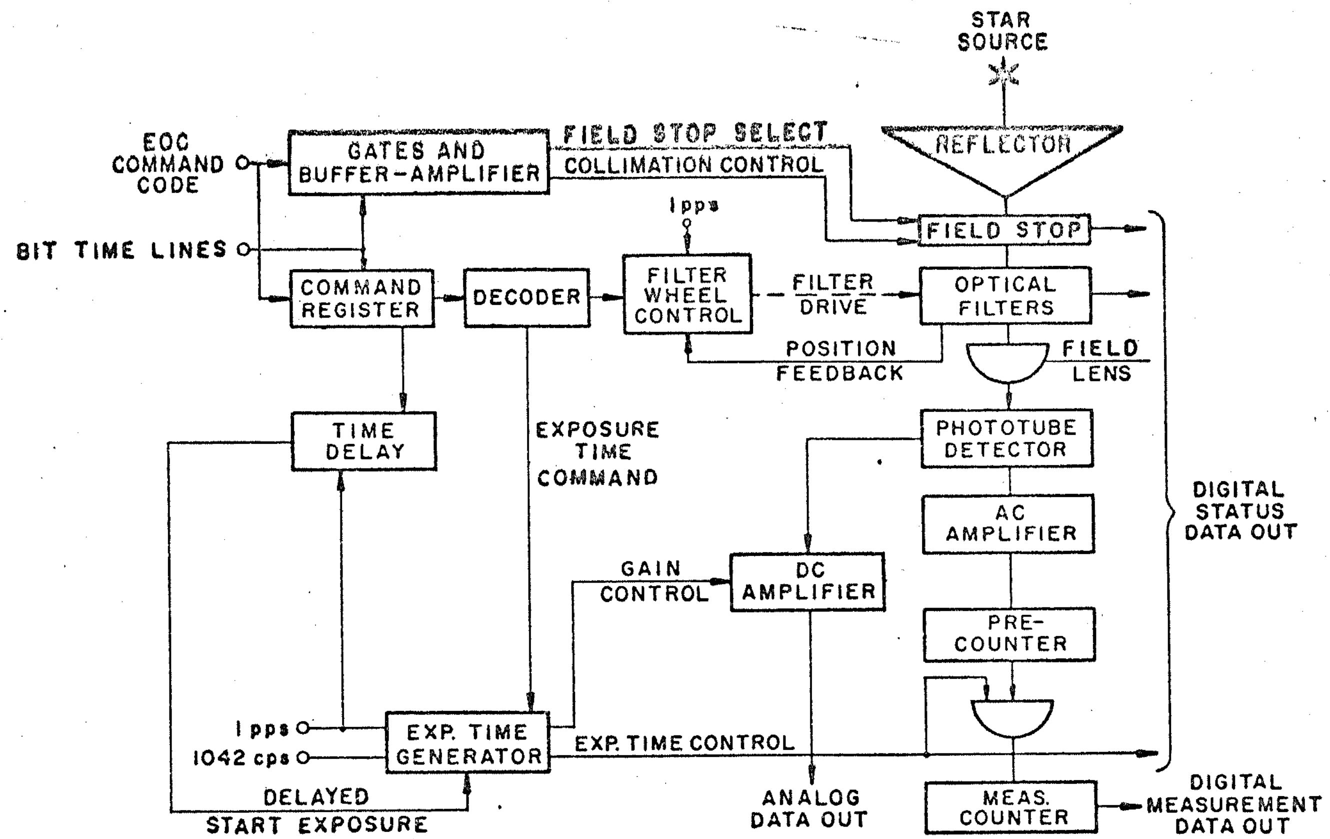


FIG. II - 1 FUNCTIONAL BLOCK DIAGRAM OF STELLAR PHOTOMETER

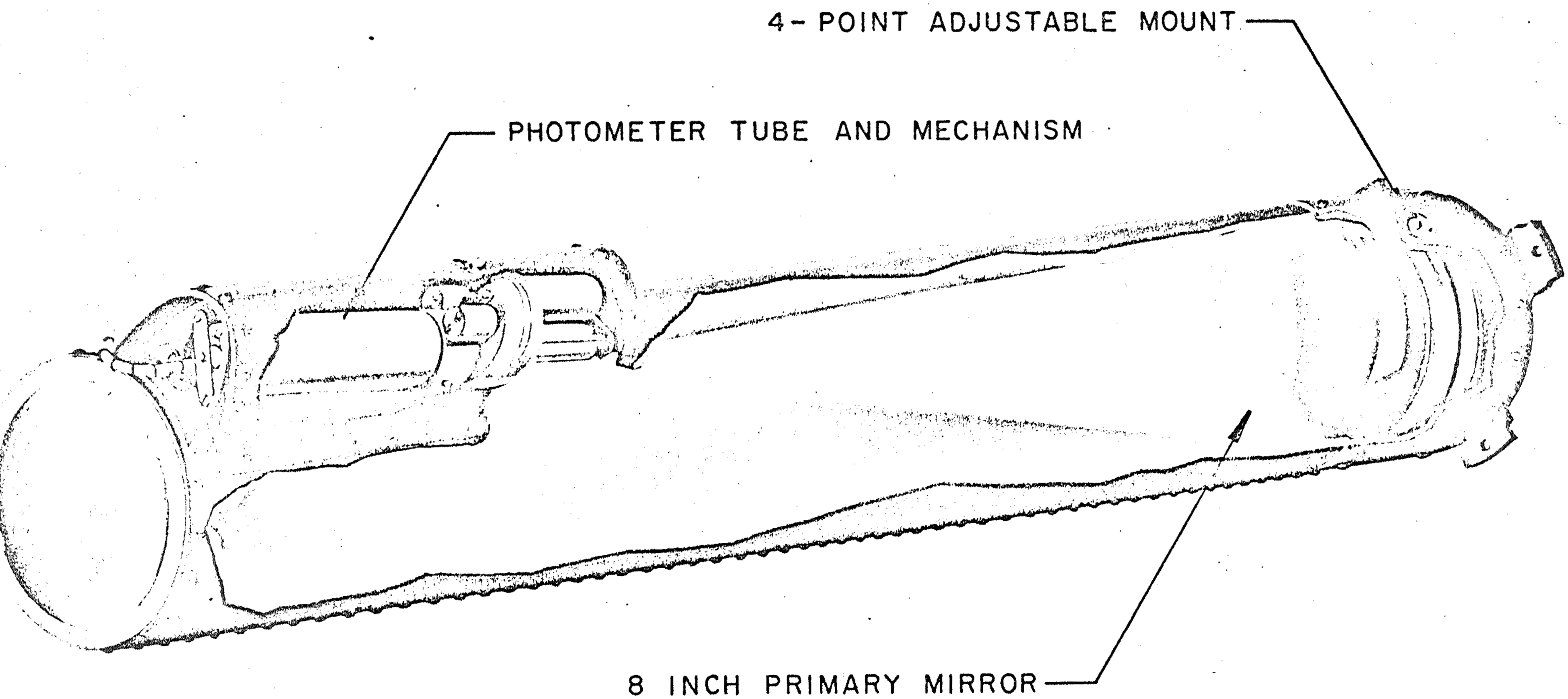


FIG. II - 2 STELLAR PHOTOMETER MODULE

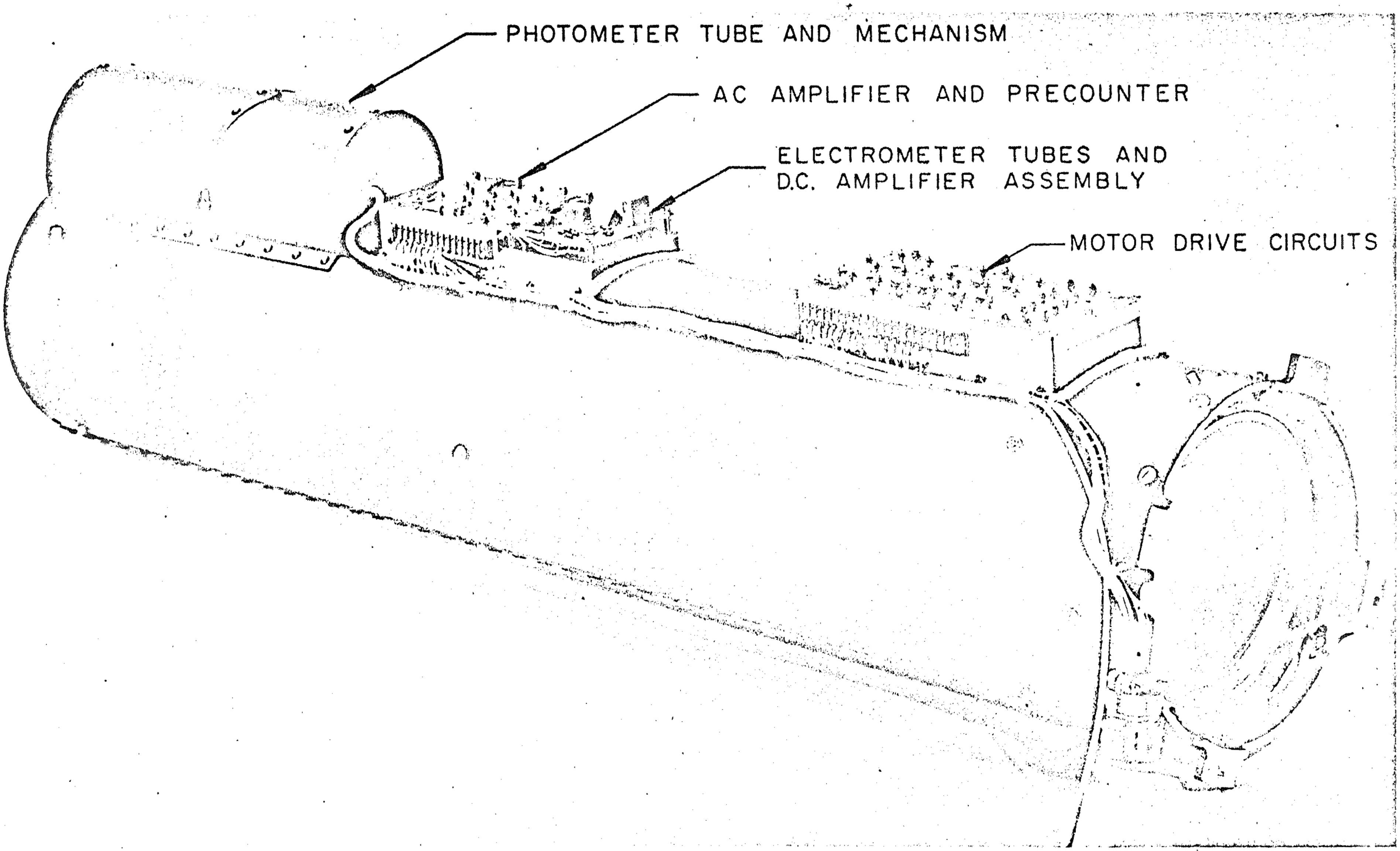


FIG. II - 3 STELLAR PHOTOMETER MODULE

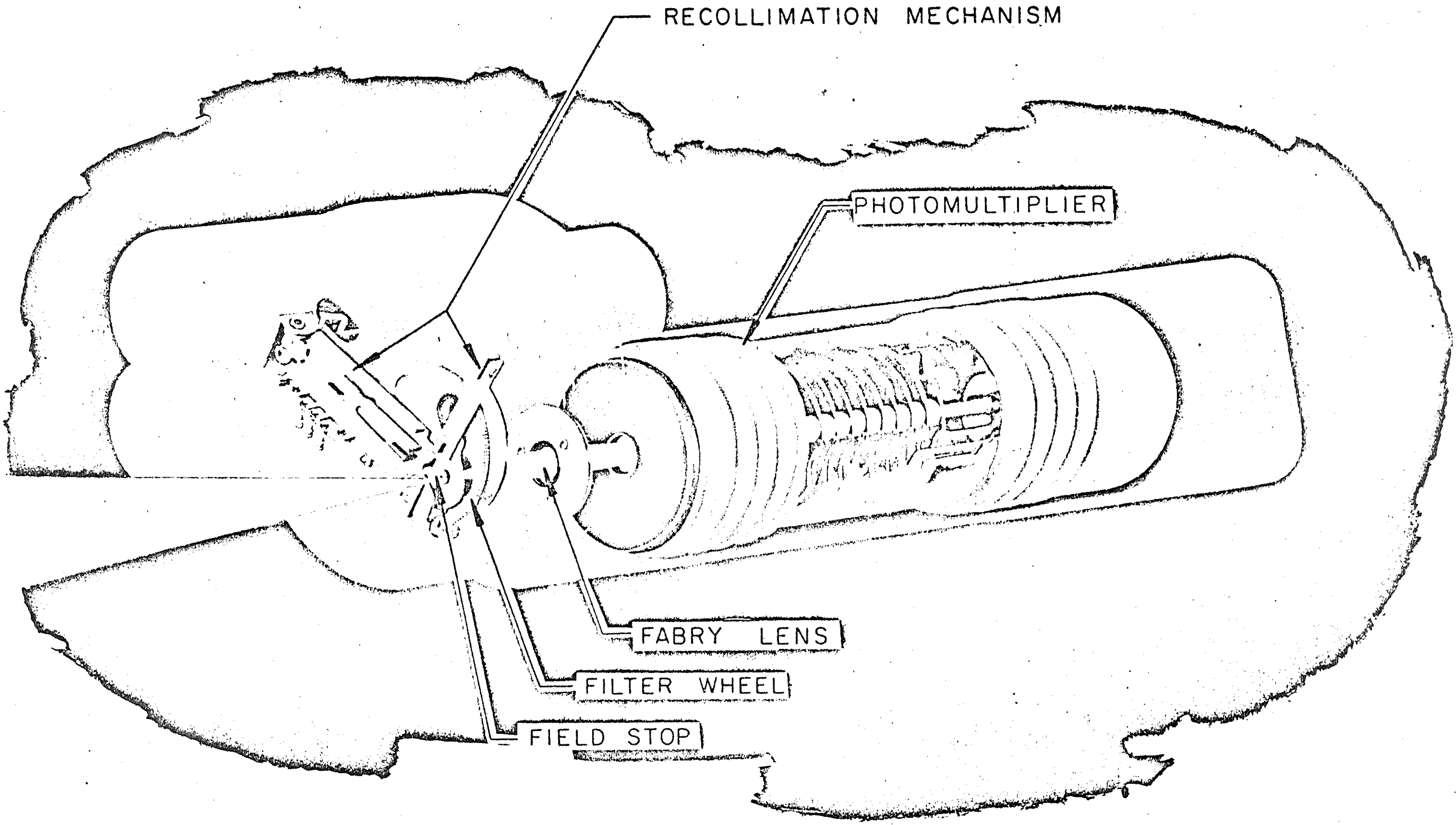


FIG. II - 4 STELLAR PHOTOMETER TUBE AND MECHANISM

FILTER ASSIGNMENT

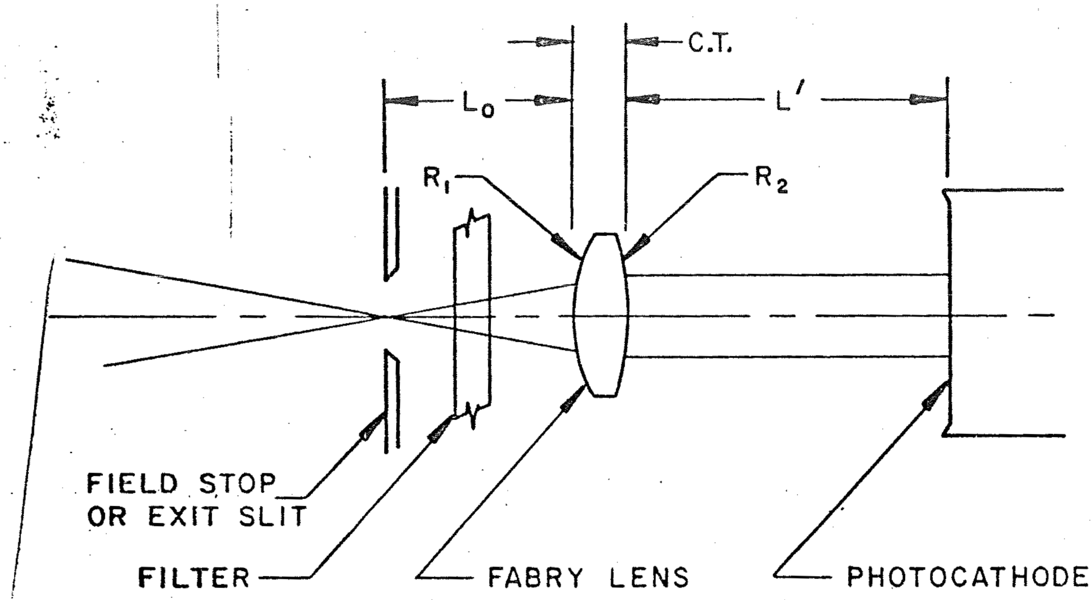
FILTER WHEEL POSITION	STELLAR PHOTOMETER # 1	STELLAR PHOTOMETER # 2	STELLAR PHOTOMETER # 3	STELLAR PHOTOMETER # 4
1	3300	900 *	1850	1500
2	DARK	2800	2200	CALIB.
3	4200	DARK	CALIB.	1250
4	2800	CALIB.	DARK	1150
5	CALIB.	2200	1500	DARK
TYPE OF DETECT.	E.M.I. 6256B	E.M.I. 6256B	ASCOP 541F	ASCOP 541F

*PHOSPHOR FILTER

FILTER CHARACTERISTICS

FILTER NUMBER	NOMINAL WAVELENGTH	MAXIMUM TRANSMISSION	BAND LIMITS AT 5% OF MAX. T.	AVG. TRANSMISSION BET. BAND LIMITS
900	670	15%	500 – 900	10%
1150	1250	19%	1100 – 1680	10%
1250	1300	16%	1200 – 1680	8%
1500	1500	21%	1220 – 1830	11%
1850	1850	24%	1600 – 2180	15%
2200	2200	26%	1920 – 2560	13%
2800	2800	29%	2500 – 3100	13%
3300	3300	29%	3060 – 3580	15%
4200	4200	29%	3980 – 4490	15%

FIG. II – 5 STELLAR PHOTOMETER WAVELENGTH DATA



MODULE	MAT'L	DIA	R_1	R_2	C.T.	L_o	L'
STEL. 1	S_iO_2	16.0	18.7	29.9	4.0	21	22.2
2	S_iO_2	17.0	22.2	29.1	4.0	21	22.2
3	L_iF	16.5	23.5	36.6	4.0	21	22.2
4	NONE	USED					
NEBULAR[3]	S_iO_2	15.0	38.6	38.6	3.0	10	0.9
	S_iO_2	15.0	18.1	PLANO	3.5	—	15.8
SPECT. 1	S_iO_2	12.0	22.2	29.1	4.0	21	22.2
2	L_iF	11.0	23.5	36.6	4.0	21	22.2

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. ALL RADII ARE CONVEX.
3. NEBULAR PHOTOMETER EMPLOYS TWO ELEMENTS. SPACING BETWEEN THEM IS GIVEN AS L' FOR FIRST ELEMENT.
4. LOCATION OF FILTERS BETWEEN FIELD STOP AND LENS NOT CRITICAL. (NO FILTERS ARE EMPLOYED IN SPECTOMETER).

FIG. II-6 FABRY LENS
CHARACTERISTICS FOR ALL MODULES

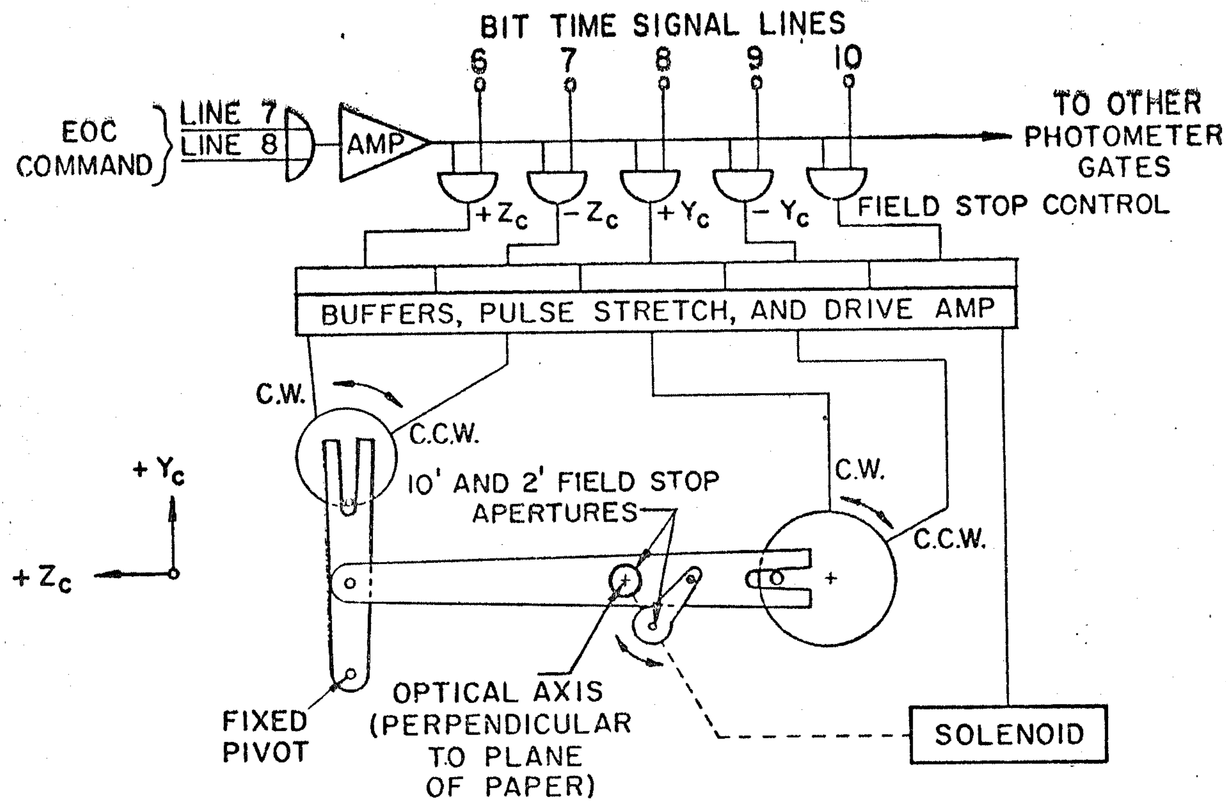


FIG. II - 7 FUNCTIONAL DIAGRAM OF COLLIMATION AND FIELD STOP CONTROL

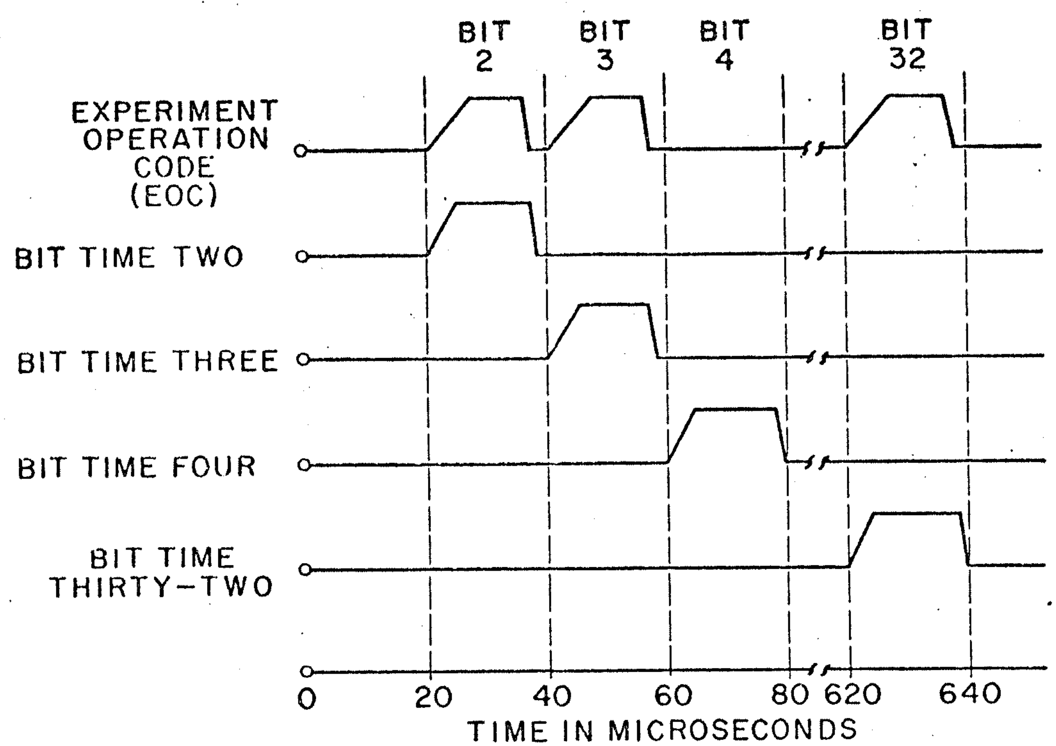


FIG. II - 8 EOC COMMAND CODE AND BIT TIME SYNCHRONIZATION

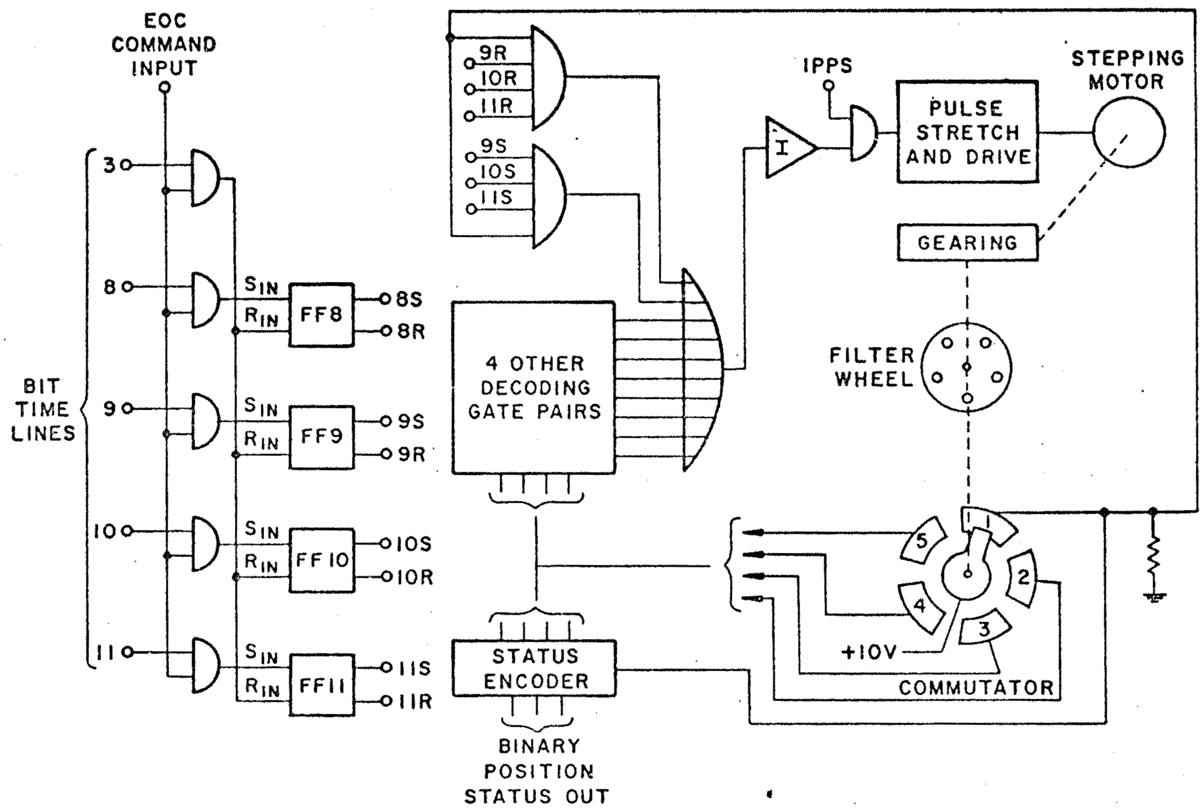
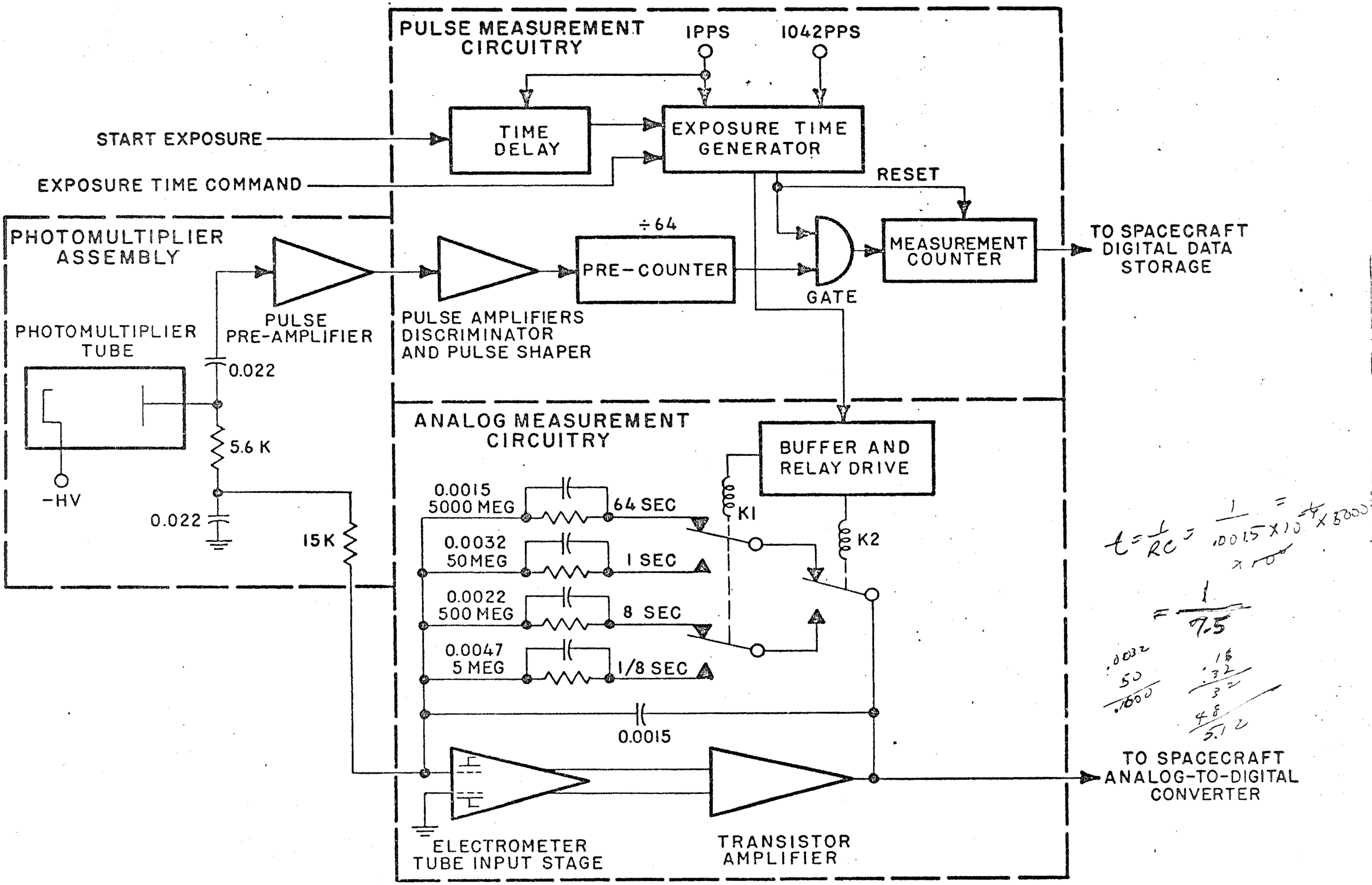


FIG. II -9 LOGIC DIAGRAM FOR FILTER WHEEL POSITION CONTROL



$t = \frac{1}{RC} = \frac{1}{.0015 \times 10^{-4} \times 5000 \times 100} = \frac{1}{7.5}$

$.0032 \times 50 = .1600$

$.16 \times .32 = 32,\ 48,\ 5.12$

FIG. II-10 FUNCTIONAL DIAGRAM OF DATA MEASUREMENT CIRCUITS

CHARACTERISTIC	PHOTOTUBE TYPE	
	ASCOP 541-F08	EMI 6256B
PHOTOCATHODE MATERIAL	Cs-Te	Cs-S O
CATHODE FACEPLATE MATERIAL	LiF	QUARTZ
SPECTRAL RESPONSE	1100-3500A	1650-6500A
NUMBER OF STAGES	14	13
TUBE DIAMETER	1.250 INCHES	2.028 INCHES
TUBE LENGTH	5-1/8 INCHES	5.118 INCHES
ACTIVE CATHODE DIAMETER	10 MILLIMETERS	10 MILLIMETERS
QUANTUM EFFICIENCY	5% — 1216A	12.5% — 4200A
NOMINAL VOLTAGE IN WEP	2350 V	1200V
MAXIMUM RATED OVER-ALL VOLTAGE	3500	2500
MAXIMUM STABLE DC ANODE CURRENT	100 UA	10UA
DYNODE RESISTORS, OHMS	15 5.6 M	1 12.0 M, 13 5.6 M
VOLTAGE CHANGE REQUIRED FOR 10 X CHANGE IN CURRENT GAIN	500V	300V

FIG. II-11 TABLE OF PHOTOMULTIPLIER TUBE CHARACTERISTICS

SECTION III

NEBULAR MODULE FUNCTIONAL DESCRIPTION

A. GENERAL

The functional block diagram of the Nebular Photometer is similar to that of the Stellar Photometers shown in Fig. II-1. The main difference between the two types is that no in-flight recollimation capability is provided for in the Nebular Photometer because its greater field of view makes such a capability unnecessary. With this exception, the functional operation of the optical-electronic path shown in the figure is equally applicable to the Nebular.

Star light in the Nebular is collected in a Cassegrain-type telescope by a 16-inch diameter on-axis parabolic reflecting mirror having a 32 inch focal length. The controlled variables in the optical electronic path are field stop selection, filter selection, and exposure time and analog sensitivity selection. A phantom view of this module is shown in Fig. III-1.

B. OPTICAL

The aperture of the primary mirror is limited by the retaining ring to a 15.585" diameter. Vignetting due to the photomultiplier assembly and its supporting spider reduces the effective collecting area to 162 square inches (1050 cm^2) for sources on the axis of the system. At off-axis angles corresponding to the largest field, the area is estimated to be reduced by 0.9 per cent.

The photometer mechanism for this module is similar to that for the Stellar modules (see Fig. II-3) except for an enlarged filter wheel and the absence of any recollimation feature. Since this instrument is designed principally for observations of nebulae and other extended-surface objects, the angular fields of view are made greater than in the Stellar Photometers. As in the Stellars, two fields are available. These have angular diameters of ten minutes and thirty minutes, the corresponding linear diameters of the field stop apertures being 0.093 inch and 0.280 inch, respectively.

The filter wheel in the Nebular Photometer is a six-position device which contains four different optical filters, a calibration source and a dark slide. The calibration source and dark slide are identical to those used in the Stellars. The filter characteristics are given in Fig. III-2. It is seen that two of the filters are duplicated in two of the Stellar Photometers, again providing redundancy, as well as capability for in-orbit cross-check and recalibration. Band passes of the remaining two filters are chosen consistent with the short-wavelength cutoff of the photomultiplier.

The Fabry lens in the Nebular Photometer consists of two UV grade fused silica elements: an equiconvex (adjacent to the filter wheel) followed by a plano-convex (plano side adjacent to the photocathode). Design data for these elements are given in Fig. III-3. The axial separation of the two elements is 0.9 millimeter.

C. ELECTRONICS

1. Field Stop Selection

For the Nebular, one of two field stop apertures may be selected providing viewing angles of 10 and 30 minutes of arc, thus, various size portions of a nebular can be observed.

The field stop mechanism is a two position device, with a commutator to provide digital status output, and is controlled in the same manner as that of the Stellar field stop mechanism. See Section II. C. 1.

2. Filter Wheel

The filter wheel control is accomplished in the same manner as in the Stellar, but with an additional input and commutator position required for the sixth filter wheel position. Again, the commutator provides filter wheel status signals.

3. Data Measurements Circuitry

The data measurement circuitry contains a photomultiplier assembly with an EMI tube, as well as pulse measurement circuitry and analog measurement circuitry which are identical to that of the Stellar Photometers. For details see Section II. C. 4.

D. SUMMARY OF ALL OUTPUT DATA AVAILABLE FROM THE NEBULAR PHOTOMETER

All output data which is obtained from the Nebular Photometer is reviewed below. The WEP digital output data is formatted into four 25-bit words as shown in Fig. VII-3. All Nebular digital data is contained in digital output words No. 1 and No. 2.

As with the Stellar, Nebular output data may be divided into two classes: photometric measurement data and status data.

1. Photometric Measurement Data

a. Digital Photometric Data

This consists of an eight-bit measurement (full scale: $2^8 = 256$ units) occupying bit positions 18 through 25 in digital output word No. 2, with bit position 18 containing the least significant bit.

b. Analog Photometric Data

The analog photometric measurement has an output voltage range of 0 to 5.06 volts, and this is ultimately digitized in the Spacecraft into an eight-bit digital word for subsequent telemetry. (Full scale: $2^8 = 256$ units, for a .0198 volt unit of resolution.) The table below shows for each of the four sensitivity ranges the averaged dc PM anode current required for full scale and for one unit of resolution. The sensitivity ranges are expressed in terms of the corresponding digital exposure.

Sensitivity Range	Full Scale Amps	Unit of Resolution Amps
1/8 second exposure	10^{-6}	3.9×10^{-9}
1 second exposure	10^{-7}	3.9×10^{-10}
8 second exposure	10^{-8}	3.9×10^{-11}
64 second exposure	10^{-9}	3.9×10^{-12}

2. Status Data

a. Filter Wheel Position Status

This information is presented in binary coded form in bit positions 20, 21, and 22 of digital output word No. 1

Filter Wheel Position	Word No. 1 Bit Positions 20	21	22
1	0	1	1
2	1	0	1
3	0	0	1
4	1	1	0
5	0	1	0
6	1	0	0

b. Exposure Time Status

This information is presented in bit positions 23 and 24 of digital output word No. 1

Exposure Time	Word No. 1 Bit Positions 23	24
1/8 second	1	1
1 second	0	1
8 seconds	1	0
64 seconds	0	0

c. Aperture (Field Stop) Position Status

This information is presented in bit position 25 of digital output word No. 1

Aperture Position (Field Size)	Word No. 1 Bit Position 25
10 arc minutes	1
30 arc minutes	0

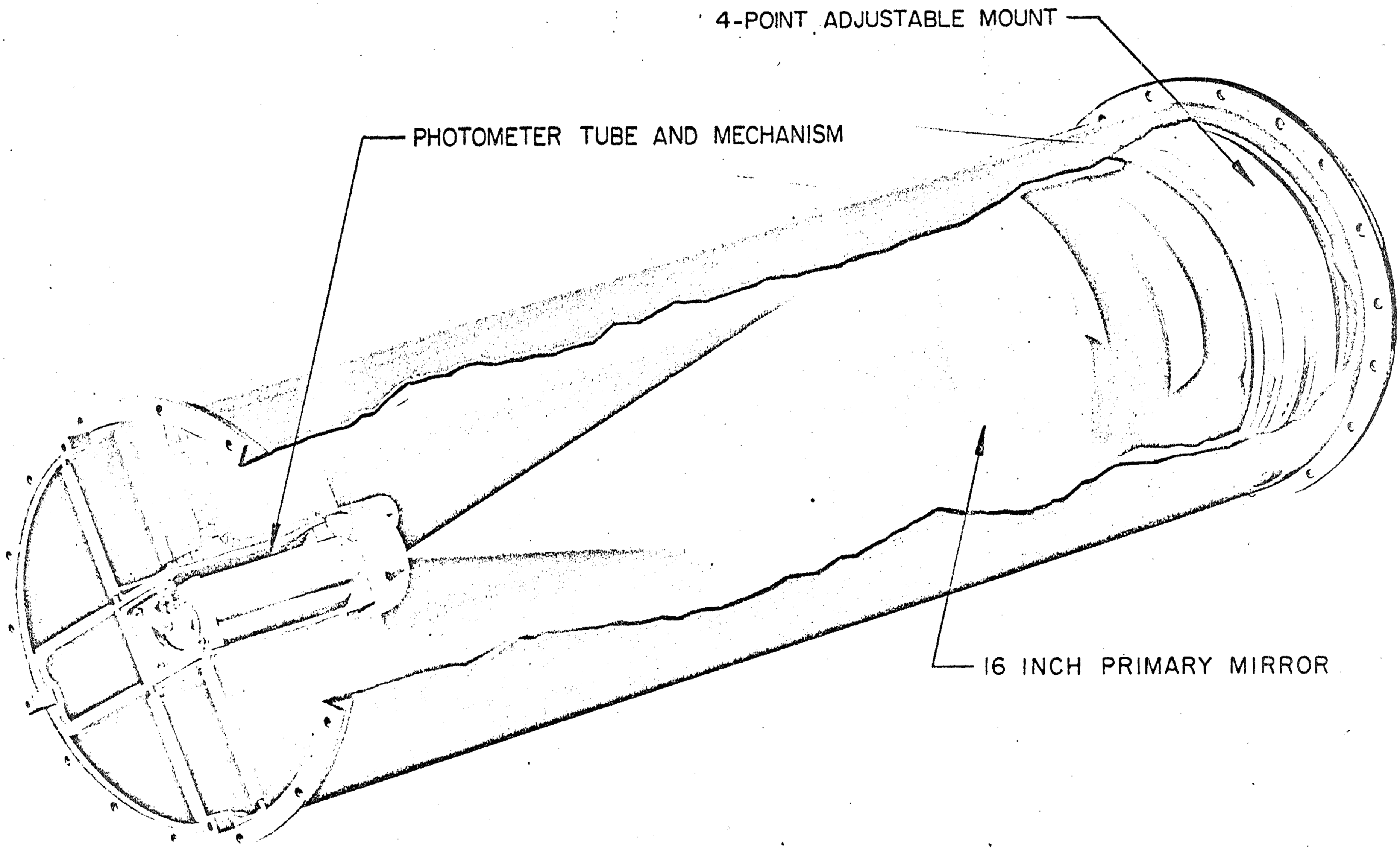


FIG. III - 1 NEBULAR PHOTOMETER MODULE

CENTER WAVELENGTHS OF FILTERS IN ANGSTROMS

FILTER WHEEL POSITION	NEBULAR PHOTOMETER
1	2000
2	2500
3	2800
4	3300
5	DARK
6	CALIB.
TYPE OF DETECT.	E.M.I. 6256B

FIG. III - 2 NEBULAR PHOTOMETER WAVELENGTH DATA

SECTION IV

SCANNING SPECTROMETER FUNCTIONAL DESCRIPTION

A. GENERAL

The functional block diagram of a Scanning Spectrometer is shown in Fig. IV-1. This diagram is applicable to both Spectrometers and shows some of the circuitry common to the two.

Because the two Scanning Spectrometers are considered to be backup instruments to the Stellar and Nebular Photometers, and because of a limitation in the amount of digital output data that the Spacecraft can accept, the equipment is constrained so that only one Spectrometer can be operated at a time. Therefore, a single command control system for the two instruments has been provided as well as command capability for selection of the desired spectrometer.

The Spectrometers collect a selected band of light by use of a rotatable grating and an on-axis parabolic mirror with a 31-1/4 inch focal length. The light from the collecting mirror passes back through a hole in the center of the grating, through an aperture slit and field lens to the photomultiplier tube. The output of the detector tube is fed through electronic circuitry almost identical to that used for the Stellar Photometers.

The controlled variables in the optical-electronic path are exit slit width selection, diffraction grating angle, and exposure time and corresponding analog sensitivity selection.

Experiment Commands are received from Spacecraft storage on Experimenters Operation Code lines. These, together with Bit Times and Clock Signals, are gated, decoded and buffered to derive the signals used to control the variables in the optical-electronic path.

B. OPTICAL

The optical design of the two Spectrometers is identical except for the amount of angular rotation imparted to the gratings and for the grating blaze angles. These are different in the two instruments to provide two different wavelength bands. A cutaway view of the system is shown in Fig. VI-2. Radiation from a stellar source impinges directly on the objective grating (no foreoptics are used) where it is dispersed before being reflected by the primary paraboloidal mirror. Thus a separate stellar image is produced in the prime focus for each wavelength. The resulting polychromatic image of a single star is a line along which the wavelength varies in an (almost) linear manner. By rotating the grating about an axis parallel to the rulings, this line image is made to scan across an exit slit placed at the prime focus. The width of the slit determines the spectral bandwidth accepted at any instant. Unwanted scattered radiation is minimized by providing a narrow mask across the face of the grating.

As in the other instruments, a Fabry lens is located behind the slit. Its characteristics for both spectrometers are given in Figure II-6.

The limiting aperture of the instrument is the grating, which has an effective collecting area of 265 cm^2 or 41.0 square inches. Wavelength coverage is 2000 to 4000Å in Spectrometer 1 and 1000 to 2000Å in Spectrometer 2. Blaze angles are set for 3000Å and 1500Å, respectively.

In both instruments the gratings are ruled with 300.06 lines per millimeter, yielding an angular dispersion of 9.656 Angstroms per arc-minute. This, combined with the primary focal length of 31.25 inches yields a linear dispersion of about 42 Angstroms/mm.

Total grating rotation required is 104 minutes in Spectrometer 1 and half this value in Spectrometer 2. In each case the interval is divided into 100 equal steps corresponding to 20 Angstroms and 10 Angstroms per step, respectively.

In each instrument, one of two slit widths can be chosen to yield high-resolution or low-resolution data. In Spectrometer 1 these are 20Å and 200Å, respectively, and in Spectrometer 2, 10Å and 100Å, respectively. The lengths of the exit slits (and the direction of the grating rulings) are parallel to the Spacecraft Z_C axis, whereas the slit widths and therefore the direction of dispersion are parallel to the Y_c axis. For spectral scanning the grating is rotated about an axis parallel to the Z_c axis. Thus if the grating drive mechanism should fail, scanning can still be achieved be slewing the entire Spacecraft about its Z_c axis.

The length of the slits limits the field of view to 8 minutes in the direction of the Z_c axis. However, because of the dispersion, the field of view is not limited in the Y_c direction by the slit width. The only limitation in this direction is that due to the mechanical vignetting caused by the opening at the front (top) end of the module. The resulting field is not a sharply defined one having more or less uniform response out to the cutoff points. Rather, it reduces in a nearly linear manner from maximum response on-axis to zero at $\pm$ 10 degrees off-axis. Therefore, any celestial object within a field measuring 8 minutes by 20 degrees may conceivably introduce spurious radiation into the system.

This effect must not be forgotten when use of the Spectrometer is contemplated. System response in the 8-minute direction of the field of view is theoretically uniform. In the 20-degree direction it is not only non-uniform but also quite unsymmetric, due to the grating blaze and spectral responsivity of the photomultiplier. This is shown graphically in Fig. IV-3, where theoretical grating efficiency is taken into account, along with Fabry lens transmission, spectral responsivity (amperes per watt) of the ASCOP 541F-08 tube, and linear vignetting of the field. The curve is for Spectrometer 2 at the nominal wavelength of 1500Å. Obviously, spurious radiation from off-axis targets will differ in wavelength from the nominal value, and this is shown in the second set of abscissas in the figure. Figures IV-4 and IV-5 show how the curves change when the grating is rotated to its two extreme positions. Figure IV-6 is analogous to Figure IV-3 except that it is for Spectrometer 1.

It must be emphasized that these curves are theoretical and are used only to illustrate the nature of the problems involved. They do not represent measured values of grating efficiencies. . Their shortcomings are evident in that no energy is shown reflected into the zero order. Spectral variation of detector response and grating reflectivity have also been omitted. All these factors (except vignetting) are lumped together in a pre-flight absolute calibration of both instruments, but the field of view problem still remains after this calibration.

C. ELECTRONICS

1. Slit Width Selection

For Spectrometer No. 1, one of two slit widths may be selected providing a bandwidth of 20Å or 200Å, while the selectable widths for Spectrometer No. 2 are 10Å or 100Å.

The slit width mechanism is a two position device with a commutator to provide a digital status output, and is controlled in the same manner as the Stellar field stop aperture mechanism. See Section II. C. 1.

2. Grating Angle

The grating drive control circuitry is such that any number of steps from 1 to the full range of 100 may be scanned. Each step is 20Å in length for Spectrometer No. 1, covering the range of 2000Å to 4000Å, while Spectrometer No. 2 covers the range of 1000Å to 2000Å in steps of 10Å each. Operation is unidirectional until a new command to reverse direction is initiated. An end-of-travel signal occurs at the stops at either extreme position of the grating level. This signal electrically inhibits further stepping attempts and switches the readout control circuitry back to Mode A for the completion of the readout cycle. The readout modes are covered in more detail in Section VII.

A commutator attached to the grating drive generates four digital status signals occurring about 25 steps apart and defining which quadrant of the 100 step scanning range is being scanned, and by noting when this status data changes three specific wavelengths may be identified (within a tolerance of not more than one step). The end-of-travel stops identify two more wavelengths.

Input commands contain information as to which Spectrometer is to be used, which direction it is to step and the desired number of steps. This command, in conjunction with timing signals generate a grating start signal which is applied to the proper motor drive circuits causing the motor to step one step. Upon completion of the selected exposure (8 or 64 seconds), and if more than one step has been commanded, the Readout Control applies the second start pulse, which results in another step. This sequence continues until the commanded number of steps have been taken or an end-of-travel signal occurs, at which time the Spectrometer drive stops awaiting a new command.

3. Data Measurements Circuitry

The data measurement circuitry for the two Spectrometers is similar to that of the Stellar Photometers. Spectrometer No. 1 contains an EMI photomultiplier tube assembly, while Spectrometer No. 2 contains an Ascop assembly.

The pulse measurement circuitry is the same except that the two Spectrometers share one measurement counter which is gated to the Spectrometer selected by the input command. Also, only the 8 and 64 second exposure times are used.

The analog measurement circuit is of the same design as that used in the Stellar Photometers, with the exception that only two sensitivity ranges are provided: 10^{-8} and 10^{-9} amps full scale. It should be noted that analog data is available continuously from both Spectrometers, while digital data is available from only one Spectrometer at a time.

D. SUMMARY OF ALL OUTPUT DATA AVAILABLE FROM THE SCANNING SPECTROMETERS

All output data which is obtained from the two Spectrometers is reviewed below. All Spectrometer digital data is contained in digital output words No. 3 and No. 4.

Spectrometer output data may be divided into two classes: photometric measurement data and status data.

1. Photometric Measurement Data

a. Digital Photometric Data

This consists of an eight bit measurement (full scale: 2^8 (= 256 units) occupying bit positions 18 through 25 in digital output word 3 with bit position 18 containing the least significant bit.

b. Analog Photometric Data

The analog photometric measurement has an output voltage range of 0 to 5.06 volts and this is ultimately digitized in the Spacecraft for subsequent telemetry into 2^8 (= 256) units, for a .0198 volt unit of resolution. The table below shows, for each of the two analog sensitivity ranges, the averaged dc PM anode current required for full scale and for one unit of resolution. The sensitivity ranges are expressed in terms of the corresponding digital exposure.

Sensitivity Range	Full Scale Amps	Unit of Resolution Amps
8 second exposure	10^{-8}	3.9×10^{-11}
64 second exposure	10^{-9}	3.9×10^{-12}

2. Status Data

a. Spectrometer Selection Status

This information is presented in bit position 1 of digital output word No. 4 and is used to correlate the digital photometric measurement data and the balance of the status data to the proper Spectrometer.

Selection	Word Bit Position 1
Spectrometer 1	1
Spectrometer 2	0

b. Wavelength Band Status

This information is presented in binary coded form in bit positions 22 and 23 of digital output word 4.

Spectrometer 1 Nominal Wave-length Band	Word No. 4 Bit Positions 22	23	Spectrometer 2 Nominal Wave-length Band
2000A - 2500A	0	0	1000A - 1250A
2500A - 3000A	1	0	1250A - 1500A
3000A - 3500A	1	1	1500A - 1750A
3500A - 4000A	0	0	1750A - 2000A

c. Exposure Time Status

This information is presented in bit position 24 of digital output word 4.

Exposure Time	Word Bit Position 24
8 seconds	0
64 seconds	1

d. Slit Position Status

This information is presented in bit position 25 of digital output word 4.

Spectrometer 1 Nominal Slit Width	Word Bit Position 25	Spectrometer 2 Nominal Slit Width
20A	1	10A
200A	0	100A

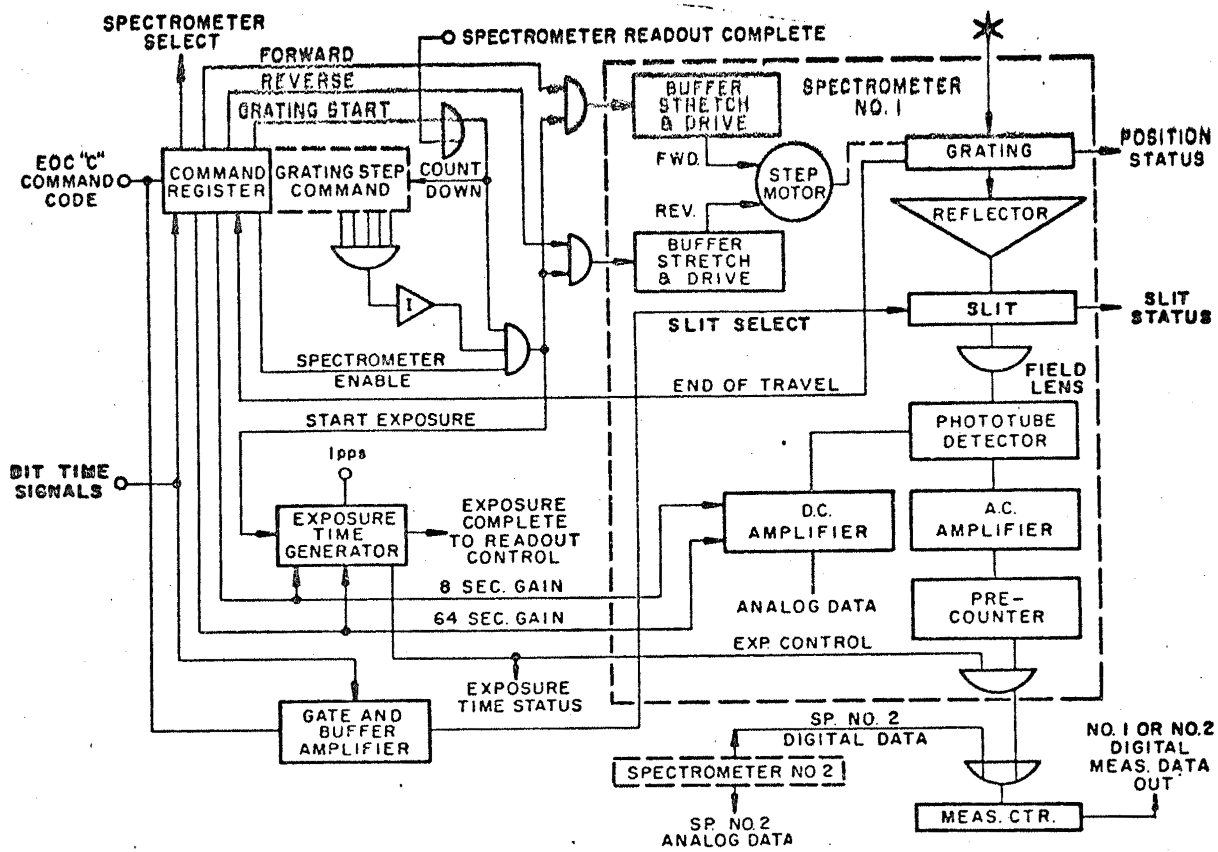


FIG. IV-1 SCANNING SPECTROMETER FUNCTIONAL BLOCK DIAGRAM

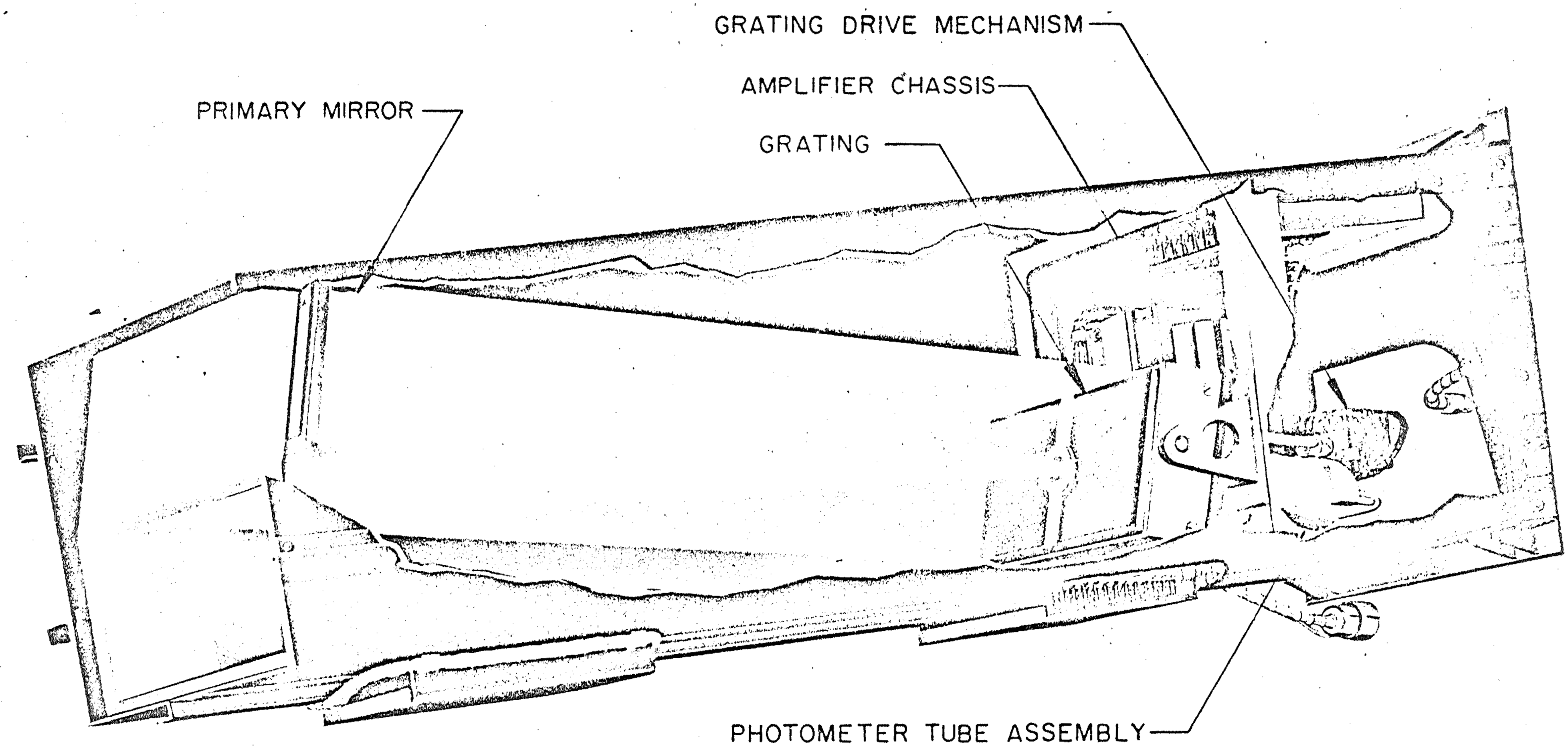


FIG. IV-2 SPECTROMETER MODULE

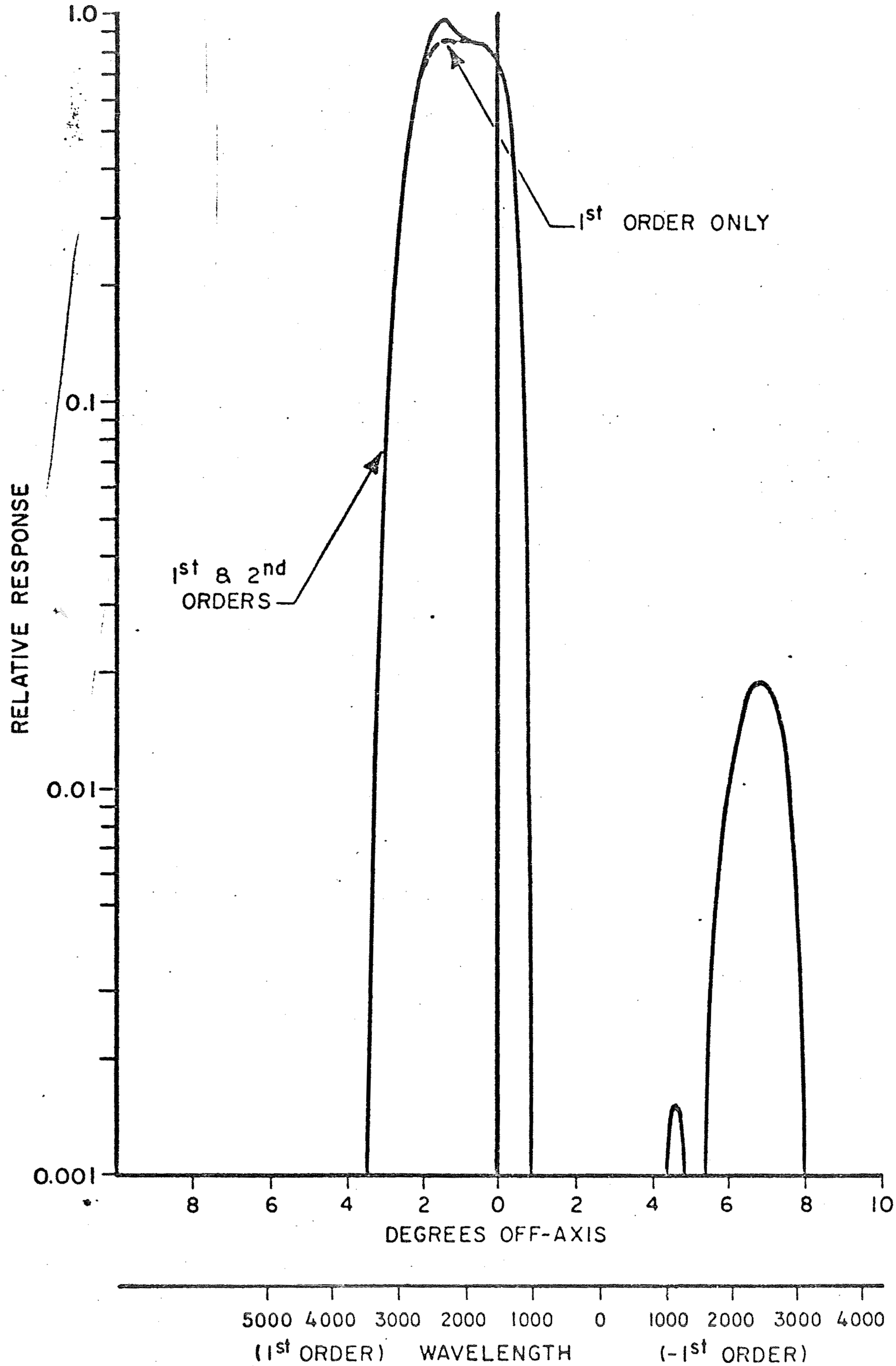


FIG. IV-3 RESPONSE OF SPECTROMETER TWO TO OFF-AXIS SOURCES

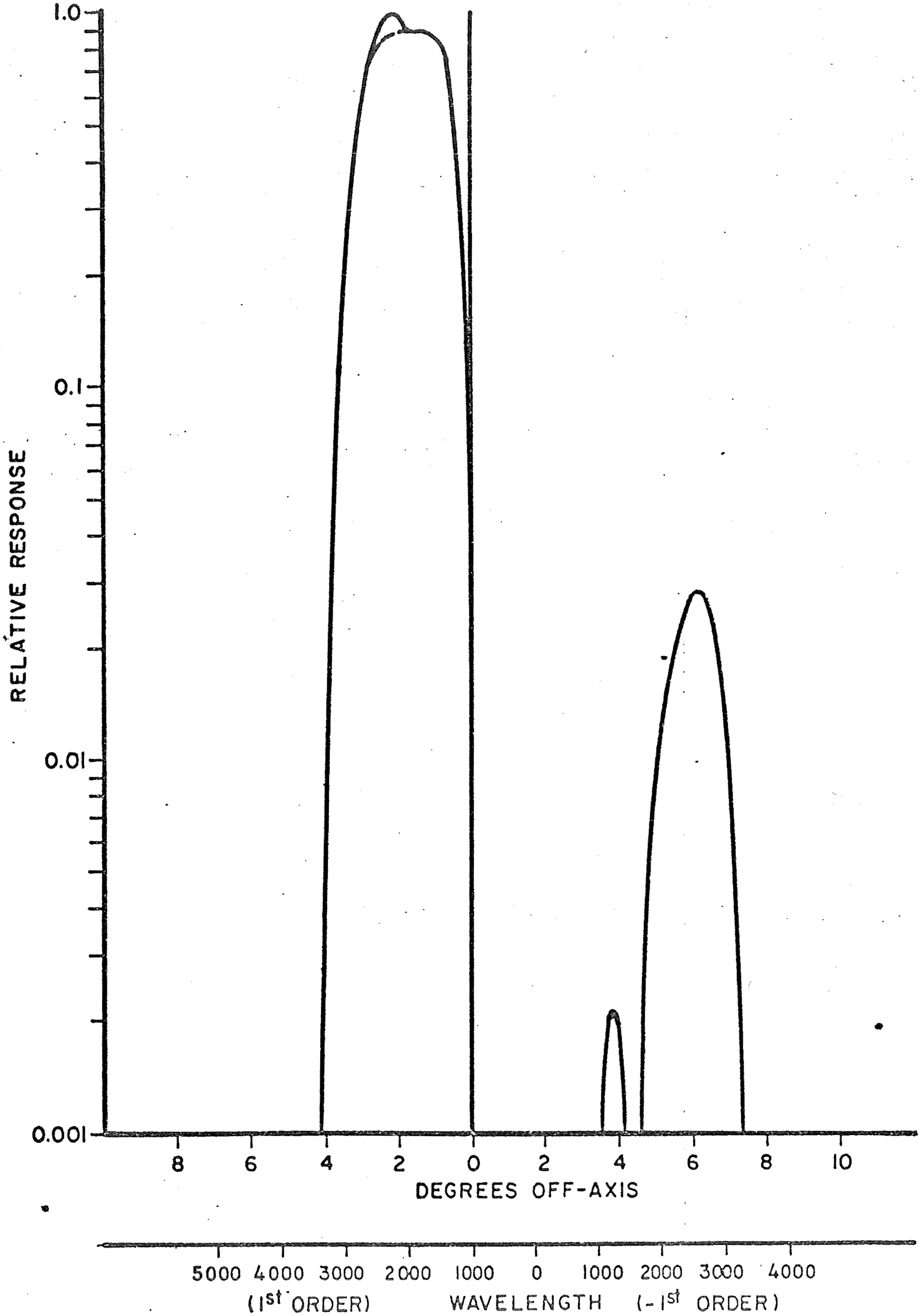


FIG. IV-4 OFF-AXIS RESPONSE, λ_{NOMINAL} = 1000 A

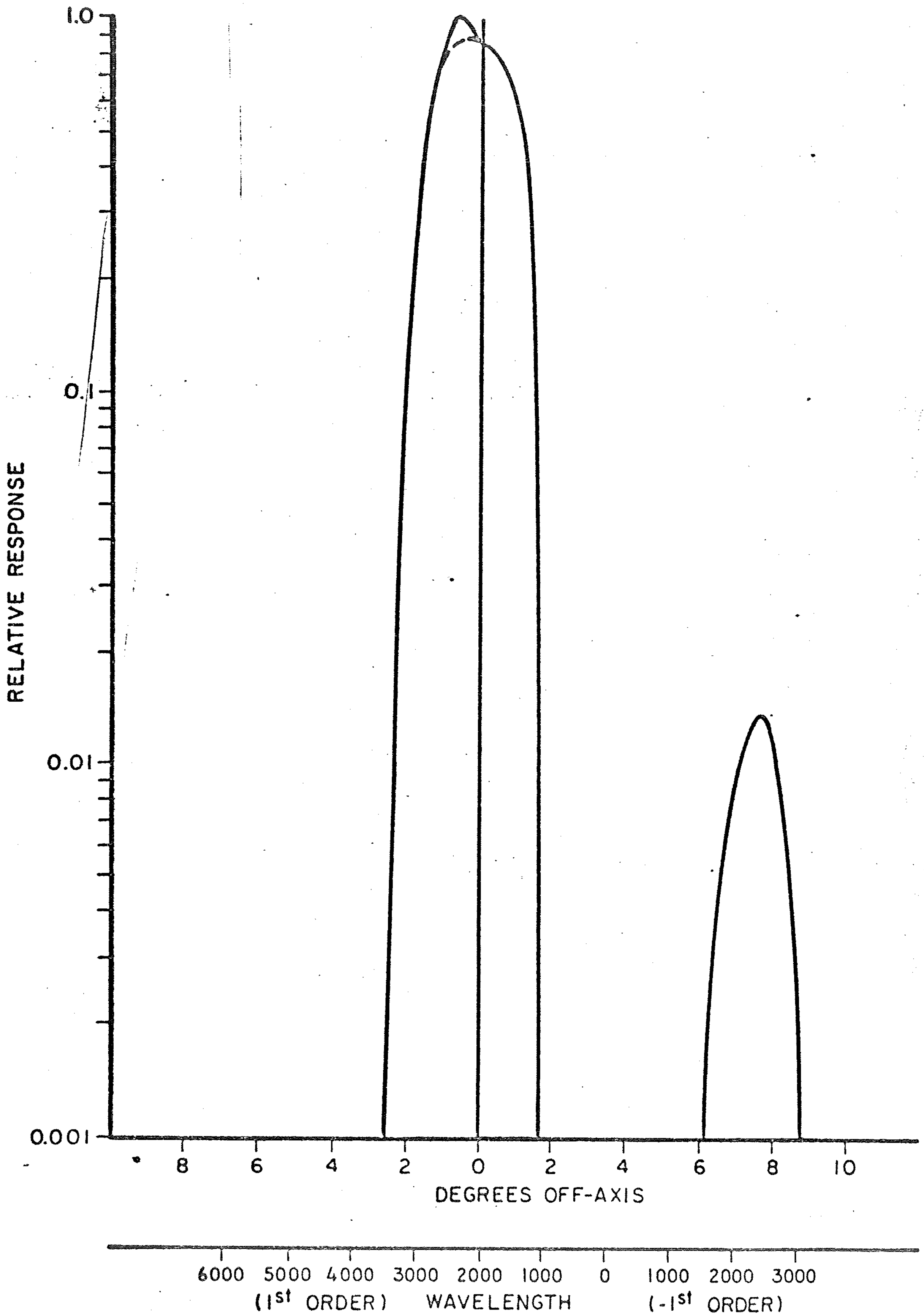


FIG. IV – 5 OFF - AXIS RESPONSE, $\lambda_{NOMINAL}$ = 2000 A

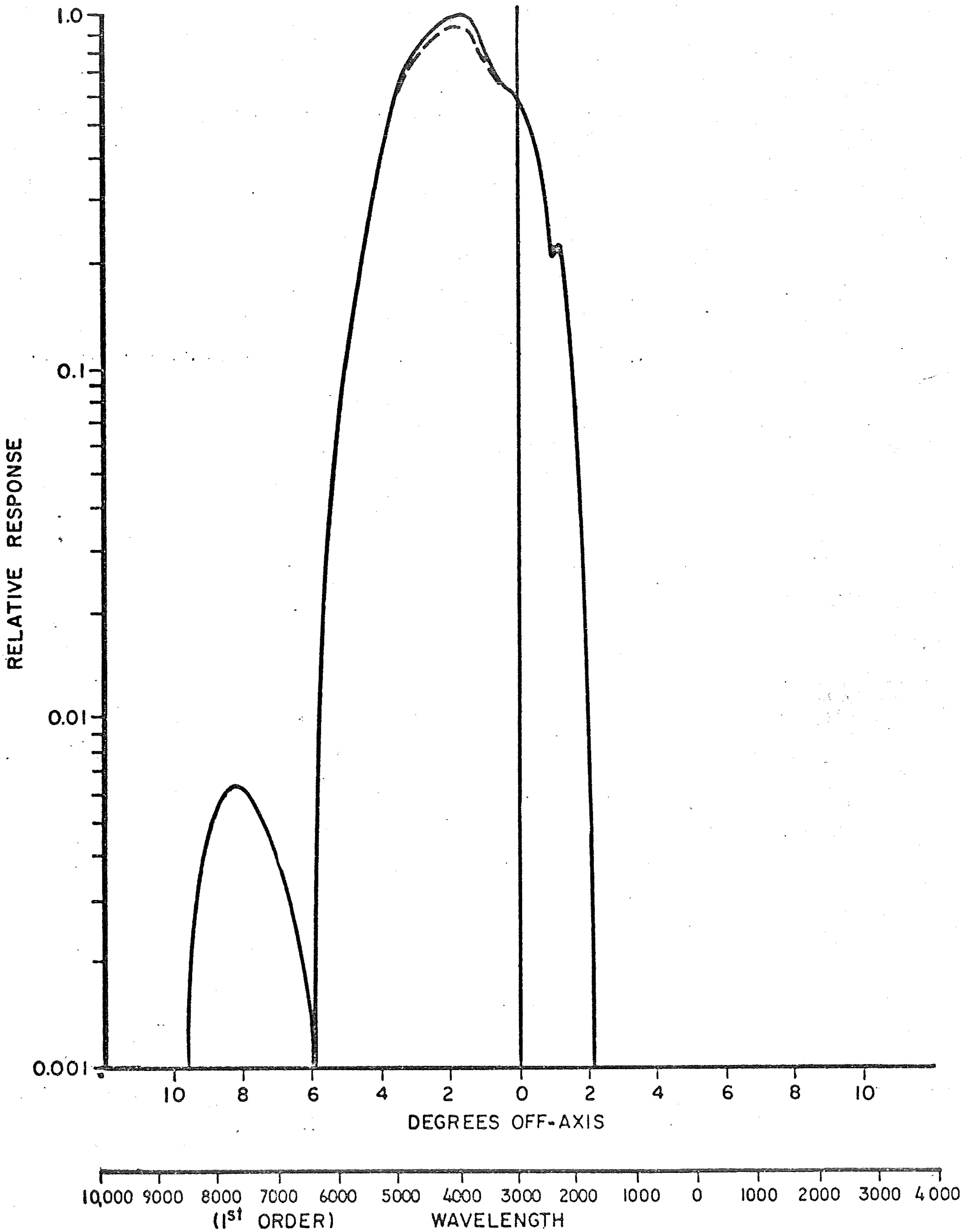


FIG. IV - 6 RESPONSE OF SPECTROMETER ONE TO OFF-AXIS SOURCES

SECTION V

MISCELLANEOUS INFORMATION

A. PULSE MEASUREMENT CONSIDERATIONS

To understand the purpose and function of the pre-counter, consider the following. Because of limitations in the Spacecraft data handling capacity, each digital photometer measurement is constrained to eight bits of data, for a full scale of 2^8 (= 256) units of intensity. Also, due to the essentially random time distribution of these pulses(random arrival of photons, etc.), the accuracy of the digital measurement must be considered on the basis of statistical probabilities. For instance, if one particular measurement completely filled the counter (i.e., 2^8 counts per exposure time) the 63% confidence level for this measurement would be $\sqrt{2^8} = 2^4$, and therefore only four of the eight bits of the digital photometer measurement would contain significant data. If, however, a total of 14 binaries were used to make this same measurement (with a corresponding increase in exposure time), then for the full scale reading of 2^{14} (= 16, 384) the 63% confidence level is $\sqrt{2^{14}} = 2^7$ (= 128), and certainly the six (probably seven) least significant bits of this measurement could be discarded, and the remaining eight bits will contain essentially all the significant data inherent in the measurement.

Thus be placing a six stage binary pre-counter between the discriminator and the actual eight stage measurement counter (and adjusting the exposure time) the size of the statistical sample is increased and greater measurement accuracy (i.e., a greater number of significant bits) is obtained.

The table below shows the average pulse rates as seen at the discriminator output for each unit of the digital output data, and for a full scale of 2^8 (= 256) units of digital output data, for the four exposure times.

Exposure Time	Pulse Rate per Measurement Unit (unit of resolution)	Pulse Rate for Full Scale Measurement
1/8 second	512 pps	131,072
1 second	64	16,384
8 seconds	8	2,048
64 seconds	1	256

It is worth noting that digital photometric measurements greater than the above "full scale" can be made if some means is available external to the counter of ascertaining the number of "dumps" (i.e., full cycles of 256 units each) the counter has made during the measurement. This might be determined from the corresponding analog data, or perhaps by extrapolating from another digital measurement of the same target using a shorter exposure time.

There should be an essentially linear correlation between the number of photons incident on the photocathode and the number of pulses at the discriminator output. However, the exact ratio of these two cannot be reliably determined because of uncertainties introduced by variations in the quantum efficiency and electron multiplication of the PM tube, in the gains of the pre-amplifier and ac amplifier, in the efficiency of the discriminator circuit, etc.

B. DC MEASUREMENT CONSIDERATIONS

The analog measurement circuit operation is described in Section II. Except for the scanning spectrometers having only two sensitivity ranges, all seven analog amplifiers are alike.

A small positive zero offset is provided to lessen the possibility of the zero drifting to negative voltages (which cannot be accommodated by the Spacecraft A-D converter) during the expected orbital life and temperature environment of the WEP. This offset voltage (approximating 0.15 volt) is provided by matched selection of the electrometer tubes and of the screen grid resistors.

Measurements made with the seven analog amplifiers of the Flyable WEP show that none of these zero offsets changed by more than 0.1 volt through the temperature range of +25°C to -45°C.

The dc amplifiers have an operational amplifier configuration and therefore are inherently linear between the limits of the zero signal (offset) voltage and the maximum usable output voltage. Measurements have verified that this linearity is at least better than ±0.5%.

The over-all gain of the analog photometric measurement channels vary with temperature. Factors contributing to this are as follows:

1. The feedback resistors must of necessity have very high resistance values (up to 5,000 megohms), and resistors in this range always have large and irregular temperature coefficients. As the feedback resistor is the main gain determining element of this amplifier design, the over-all amplifier has a similar temperature coefficient.

Laboratory measurements show changes in resistance and of amplifier gain of 6 to 20 percent over the range of temperatures from +25°C to -55°C.

2. It is known that the over-all radiant sensitivity of a photomultiplier tube is temperature-dependent, but to date, no calibration data specifically related to temperature dependence has been taken on the flyable tubes. However, the variations appear to be in the order of tens of percent over the anticipated temperature range.

It is planned that calibration measurements will be performed on the entire WEP using the temperature and vacuum optical facilities at Goddard Space Flight Center some time before launch, at which time an addendum to this document may be issued.

C. GENERAL STATUS DATA

The temperature at three places in the experiment and the output voltages of all three dc-dc converter systems are continuously monitored, and the resulting analog information is fed directly to the Spacecraft where it is converted to digital form and stored for later transmission to a ground station.

Since the Spacecraft A-D converter will digitize only voltages between 0 and +5.06 v, some of these parameters must be shifted in range before being fed to the Spacecraft. For the +10 and +15 volt supplies, this is provided by simple voltage dividers, and calibration curves with positive slopes result. See Figs. V-1 and V-2. For the negative supplies (-10 volts, -15 volts, and -2500 volts) the status must necessarily be referenced to a positive voltage, and the resulting circuits producing families of curves with negative slopes. These curves and circuits are shown in Figs. V-3, V-4, and V-5, respectively. In the case of the -2500 volt supply, the impedance of the voltage divider was necessarily very high, and an impedance transformation was necessary to avoid loss of accuracy due to excessive loading of the status data circuit by the A-D converter. This is provided by a temperature compensated emitter follower circuit.

Temperature is sensed at three places in the WEP by thermistors. One of these is located in the Control Electronics Package, one near the middle of the Primary Structure and one on the top flange of the Nebular Module. Families of curves for these are provided in Figs. V-6, V-7, and V-8.

D. POWER AND FUSING

The primary power for the WEP is obtained from the 28 v ±2% Spacecraft power supply. In the WEP, this 28 v is directed to the following circuit areas:

(1) The 10 v dc-dc converter system

(2) The 15 v dc-dc converter system

(3) The HV dc-dc converter system

(4) The energy storage capacitor system.

The heart of the 10 v dc-dc converter system consists of a redundant pair of dc-dc converters, either one of which is capable of supplying the total WEP requirements for +10 and -10 v power, and only one of which is used at a time. The system also includes suitable digital logic and relay switching circuits such that in the event of a suspected failure of one of the converters, the other may be switched into use via ground command. This system is located physically in the Control Electronics Package.

The +10 and -10 v power is used extensively in the a-c amplifier and motor drive circuits of the Prime Instrument Package. It is also used as reference voltages in the temperature sensor circuits.

The 15 v dc-dc converter system also contains a redundant pair of converters, switchable by ground command. This system is located on the underside of the primary structure in the Prime Instrument Package and supplies power to the analog amplifiers and to some of the analog status data circuits.

Like the two systems described above, the HV dc-dc converter system contains a redundant pair of converters switchable by ground command. Each converter is capable of delivering 165 microamps at -2500 v with a regulation of 0.1% for anticipated line, load, and orbital temperature variations. The steady state load is 140 microamps. This system is also located on the underside of the primary structure, and is used only for the photomultiplier tubes.

The energy storage capacitor system consists of six essentially identical and electrically independent sets of capacitor banks, as shown in Fig. V-9. These are charged from the 28 v line, and furnish the relatively high peak 28 v power which is necessary to drive the various motors, solenoids and relays, and which is not available directly from the Spacecraft. One of these banks, of 2400 microfarad capacity, is used with each of the four stellar photometers. One bank of the same size is used for the two spectrometers (only one of the latter may be operated at a time.) The sixth bank, of 3000 microfarads, is used for the nebular photometer.

Each bank is provided with a redundantly fused current limiter circuit to limit the charging current drawn from the Spacecraft to an acceptable value.

In addition, each capacitor within the bank is also fused and is isolated with diodes so that the shorting of one capacitor will not affect the operation of the balance of the bank.

Since all actuators are of the pulse type, and the commands are limited to a maximum rate of one per second, the storage circuits will supply the necessary power and then recover before the next command appears.

In addition to the capacitor bank fusing described above, the 28 v input to each of the six dc-dc converters is independently fused, and both the +10 v and the -10 V into each of the seven telescope modules is independently fused. All fuses consist of redundant pairs (or threesomes) of fuse elements, connected in parallel, any one of which will safely take the full anticipated load. The 28 v line is not fused in the Spacecraft.

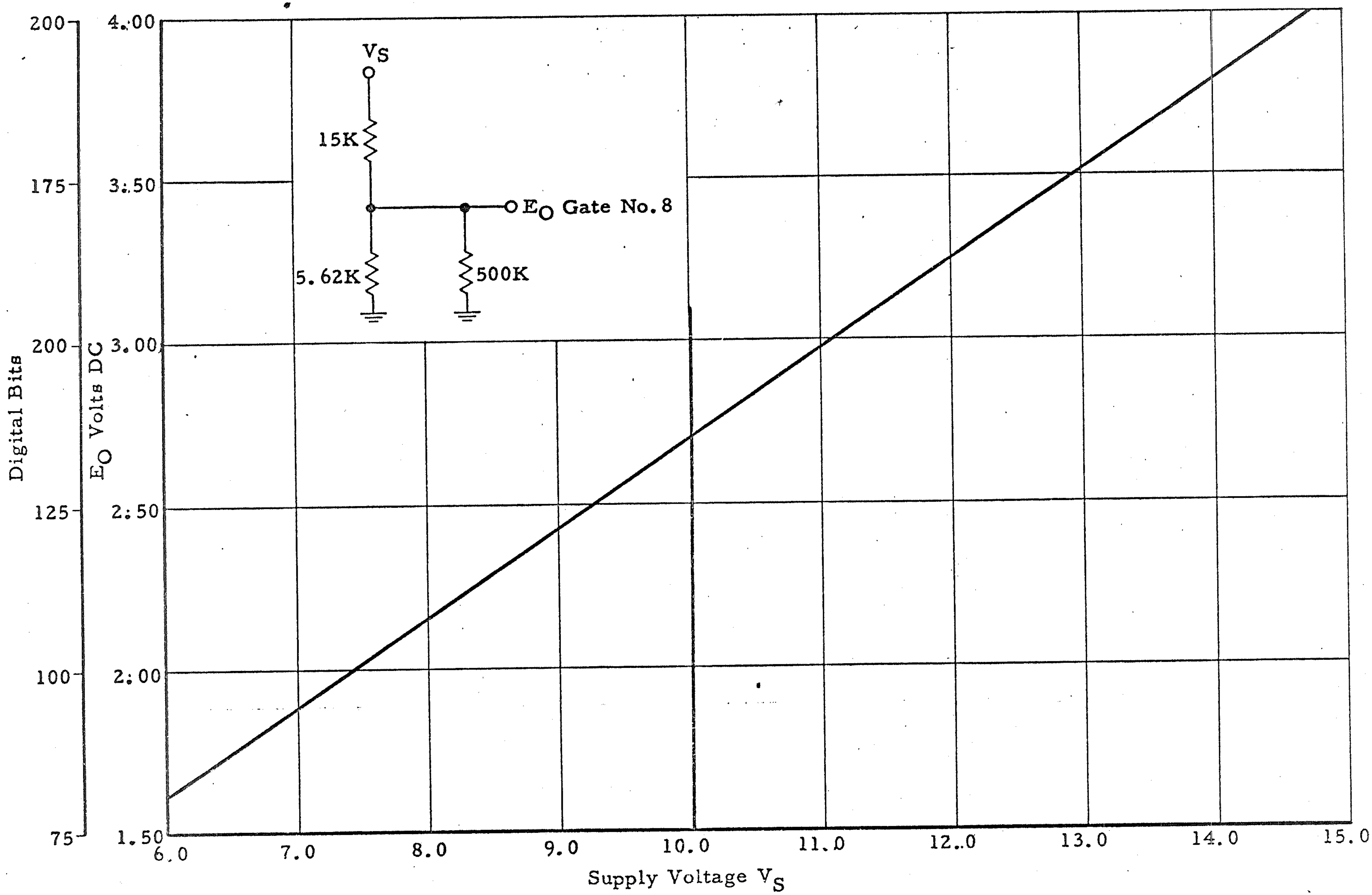
The total power required for operation of the entire WEP is as follows:

(1) Standby power (i.e., no mechanical actuations) is 7.6 watts.

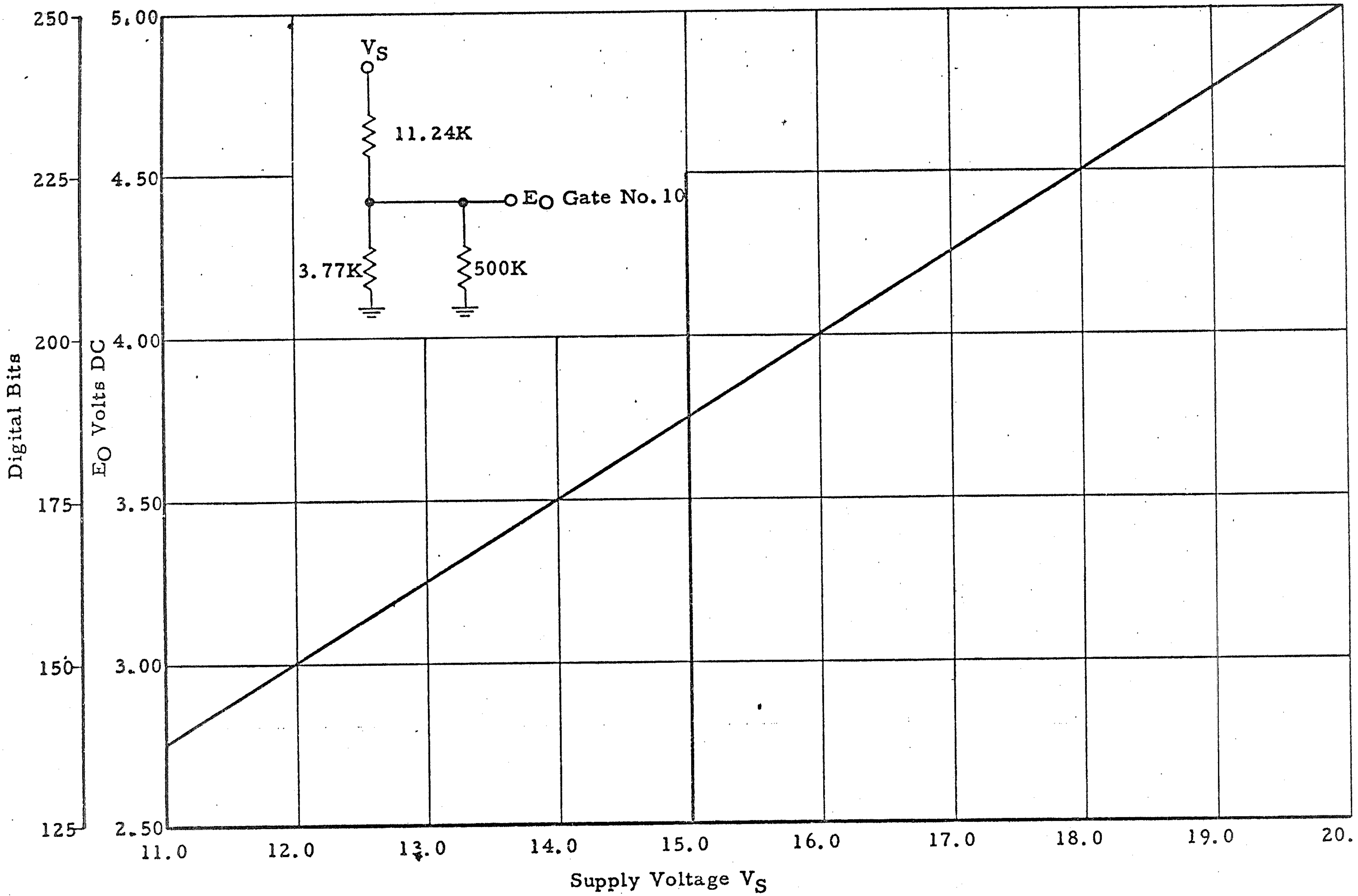
(2) Peak power during execution of commands involving mechanical actuations is 20 watts, decaying exponentially to standby with a 250 millisecond time constant.

(3) Maximum power required for execution of commands, averaged over one minute is 9.5 watts. (Note: Commands cannot be issued from Spacecraft storage more frequently than one per minute.)

(4) Turn-on surge power is 50 watts peak, decaying exponentially to standby with a 250 millisecond time constant.

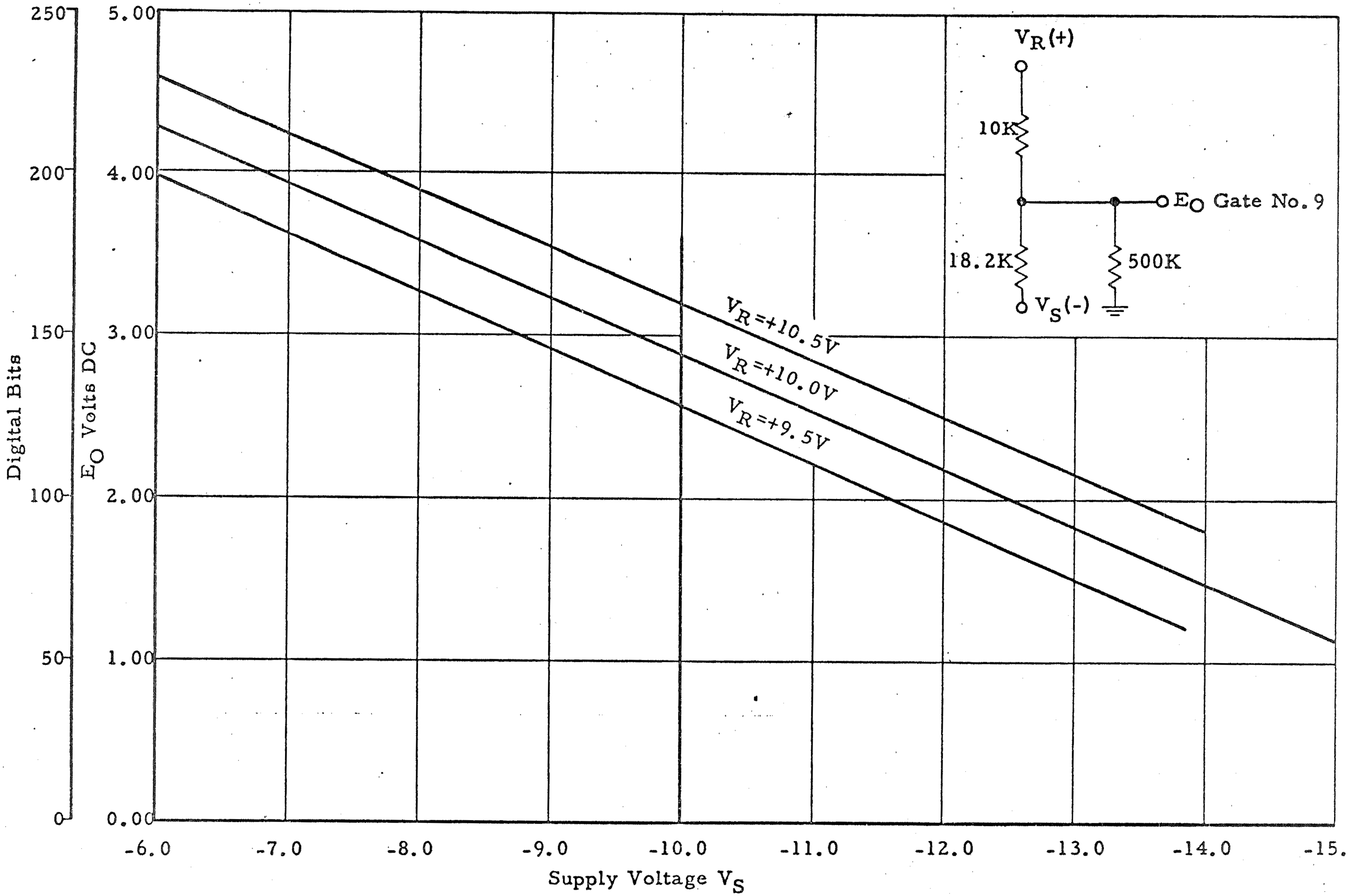


CALIBRATION CURVE FOR 10 VOLT DC-DC CONVERTER STATUS POSITIVE OUTPUT



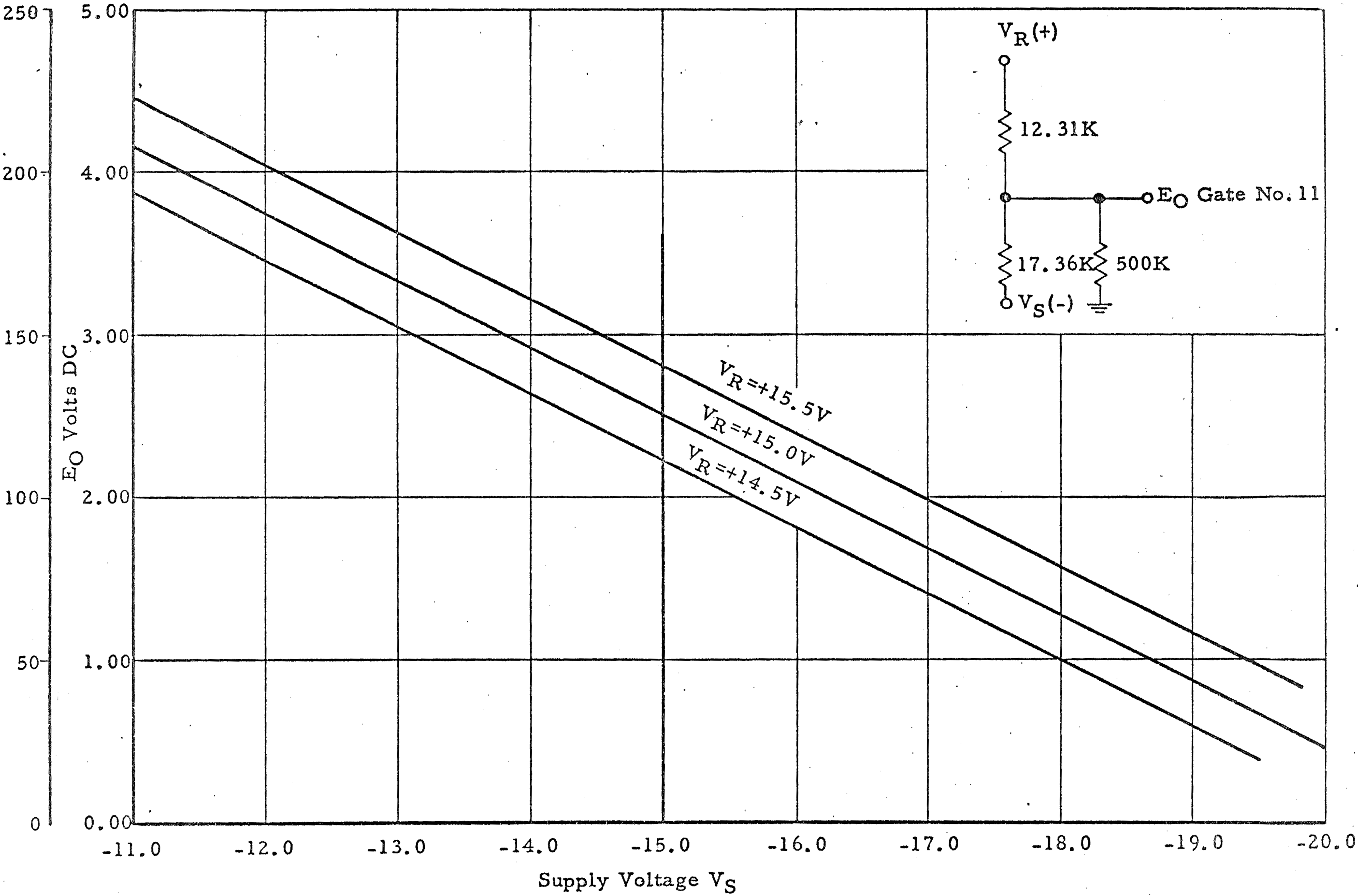
CALIBRATION CURVE FOR 15 VOLT DC-DC CONVERTER STATUS POSITIVE OUTPUT

FIG. V-2



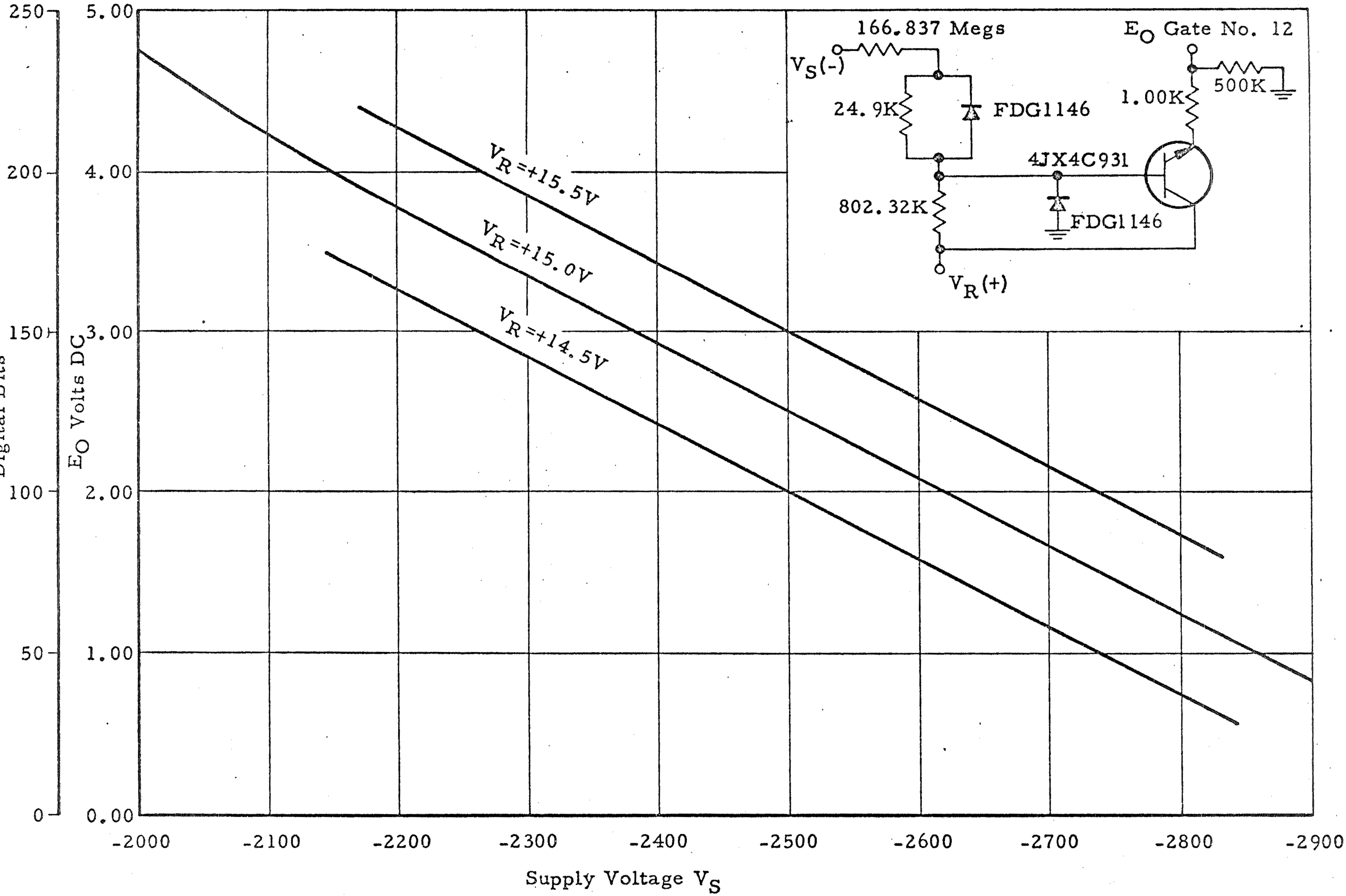
CALIBRATION CURVE FOR 10 VOLT DC-DC CONVERTER STATUS NEGATIVE OUTPUT

FIG. V-3



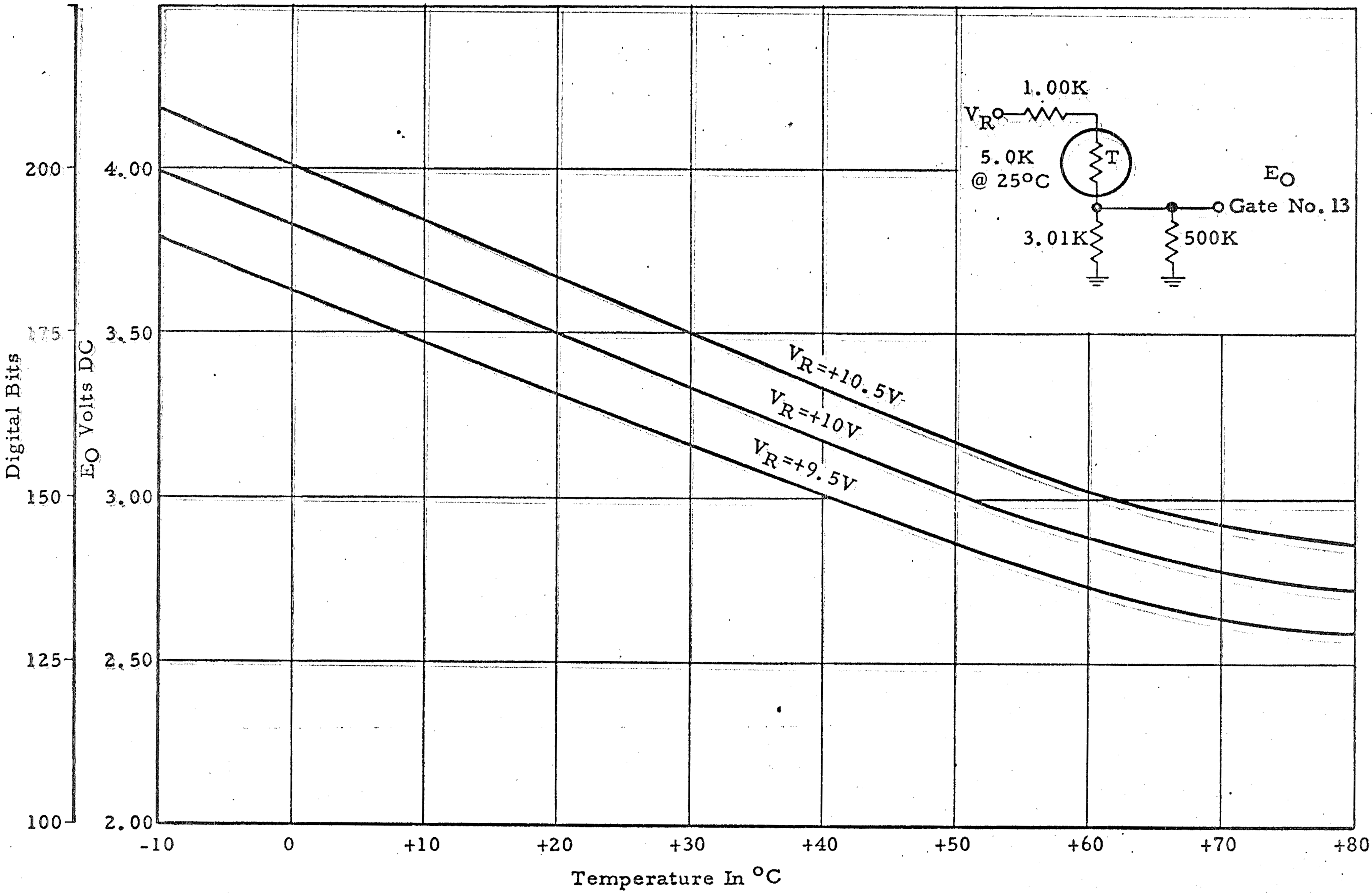
CALIBRATION CURVE FOR 15 VOLT DC-DC CONVERTER STATUS NEGATIVE OUTPUT

FIG. V-4



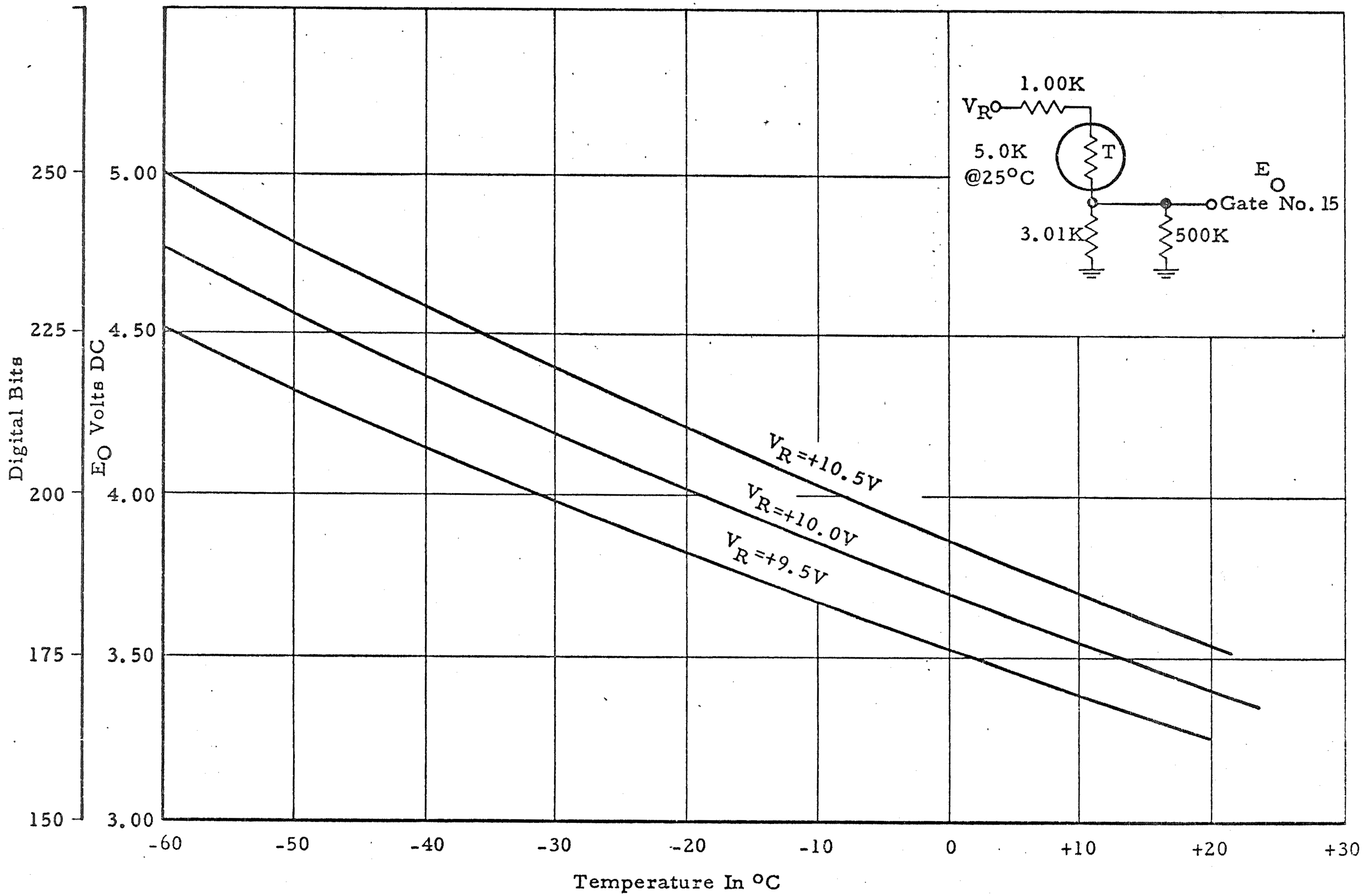
CALIBRATION CURVE FOR HIGH VOLTAGE DC-DC CONVERTER STATUS

FIG. V-5



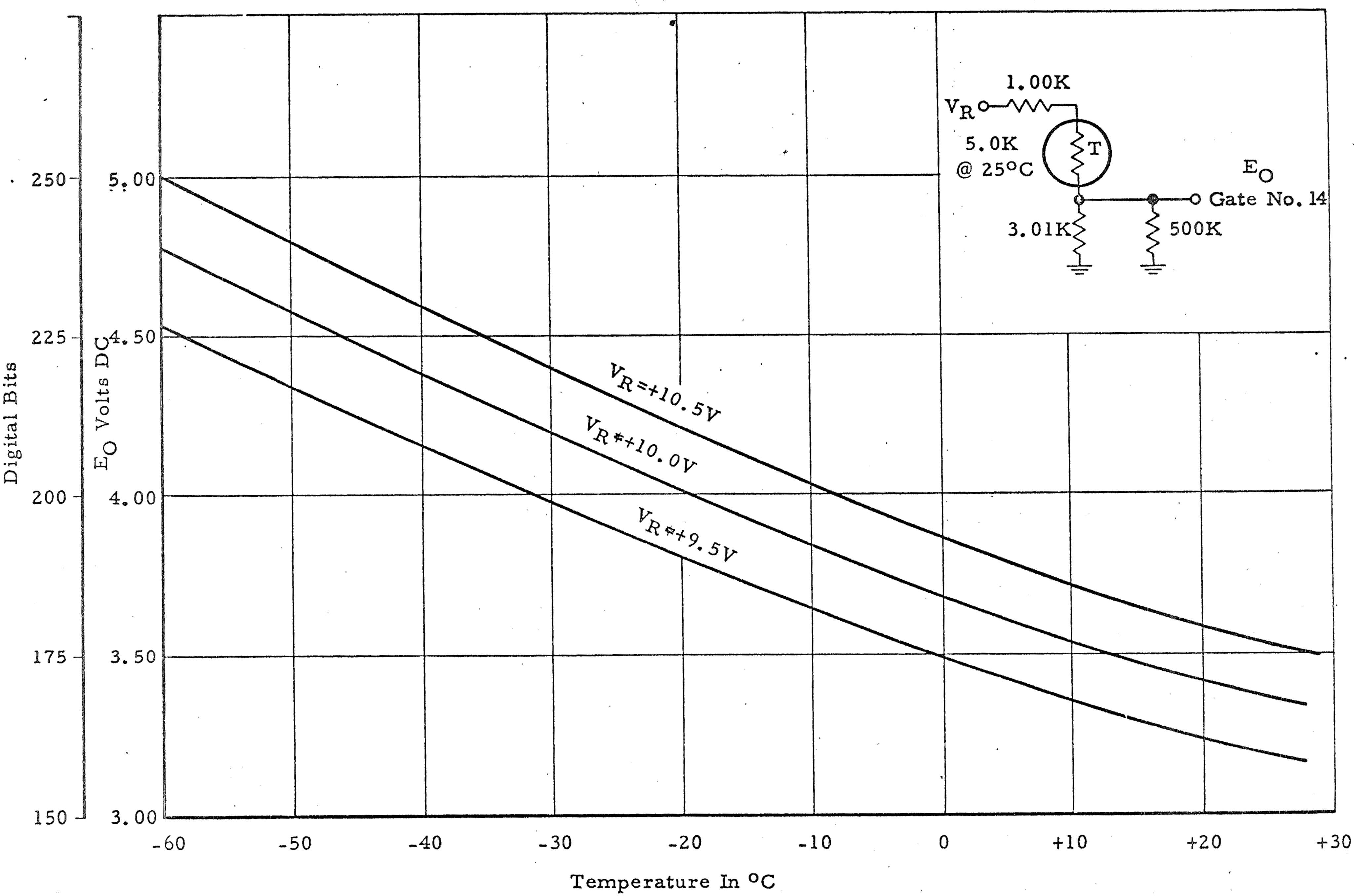
CALIBRATION CURVE FOR CONTROL ELECTRONICS TEMPERATURE SENSOR

FIG. V-6



CALIBRATION CURVE FOR PRIMARY STRUCTURE TEMPERATURE SENSOR

FIG. V-7



CALIBRATION CURVE FOR NEBULAR TOP TEMPERATURE SENSOR

FIG. V-8

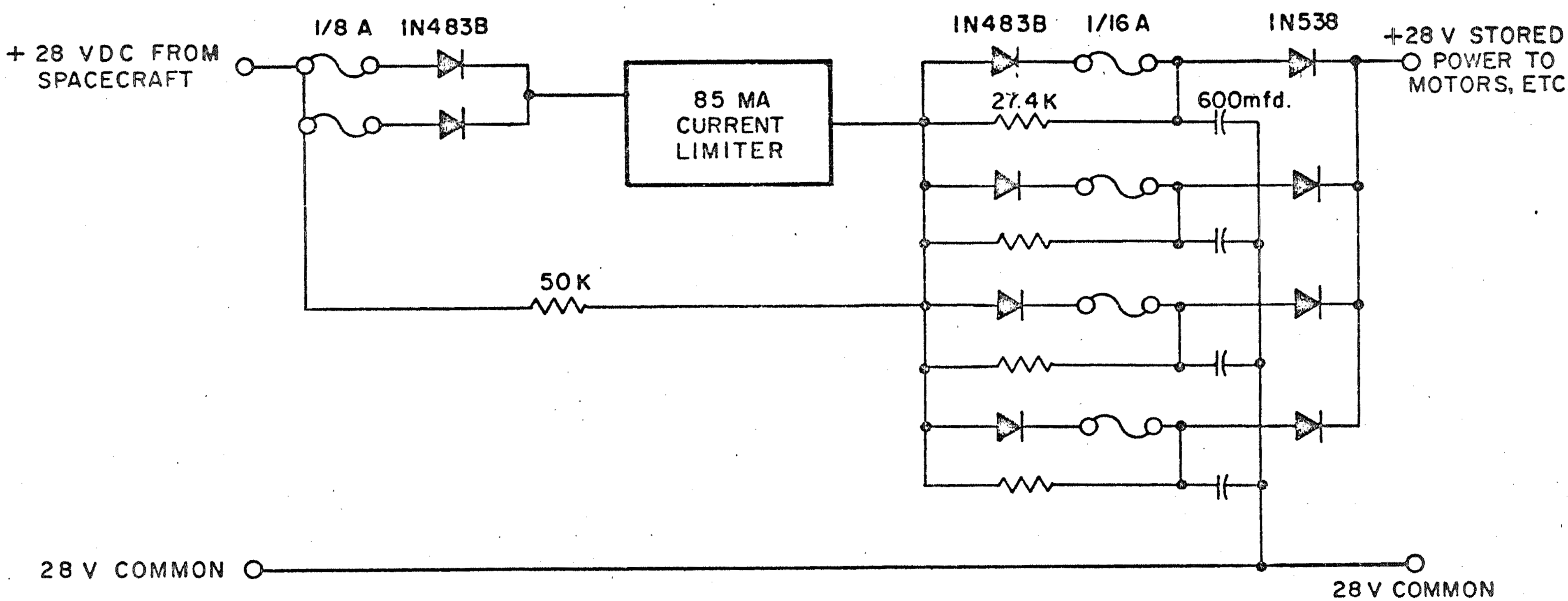


FIG. V-9 TYPICAL ENERGY STORAGE CAPACITOR CIRCUIT

SECTION VI

CALIBRATION OF PHOTOMETERS

(This Section will be prepared by the Space Astronomy Laboratory and inserted at a future date.)

SECTION VII

OPERATIONAL USAGE

A. MODES OF WEP OPERATION

The modes of operation of the WEP are directly associated with the primary instruments to be utilized for any given measurement. Each mode (and/or instrument) is commanded with, and controlled by, the EOC line on which its command appears. The OAO-WEP command codes utilized in each of these modes and the coded operation function associated with each EOC line and each bit on that line is shown in Fig. VII-1.

Mode A is associated with operation of the four Stellar Photometers and the normally used commands for these instruments. Mode A commands are received via EOC line 1, 2, or 3. Mode B is associated with operation of the Nebular Photometer. Mode C is associated with operation of the Scanning Spectrometers. Mode D is the collimation and aperture control mode of operation normally used only in early flight orbits for minor re-alignment of the four Stellar Photometers to the Spacecraft aiming axis. An "Experiment Analog Mode" causes repetitive readout of the experiment analog data frame until a new Command Enable signal is received. EOC line 13 is utilized for routing commands to a power supply switching circuit when it is desired to change any of the WEP internal power supply sources.

B. DATA FRAMES AVAILABLE

Fifteen analog channels are made available by the spacecraft for the WEP analog output data. A single frame of this data is identified in

Fig. VII-2. This data may be synchronously sampled by Experiment Data Handling Equipment (EDHE, located in the spacecraft) during real time operation. However, in the normal "stored mode" of operation, the WEP must provide a Store Analog command to the EDHE for the 15-word frame of WEP analog data (Experiment Analog) to be read into the Spacecraft data storage.

Wisconsin Experiment digital output data is formatted into four 25 bit words as shown in Fig. VII-3. Here again, this single frame of four digital words may be synchronously sampled by the EDHE. Howeve due to the nature of the asynchronous times of data availability and the limited capacity of data storage, the normal mode of operation requires that the Experiment program these data words to the data handling equip Thus, four Store Digital Word lines are available to the Experiment, one storage of each digital word. The WEP itself requires that these words sampled as a group (although not at the same time) and consequently thes words are classified as an Experiment Digital (ED) word frame.

Since it is required to know where the Spacecraft is pointing (and t where the instruments are pointing,) the Experiment is capable of programming a 64-word Spacecraft data frame which includes Spacecraft gimbal pointing angles. This data frame is designated Spacecraft status data. It is programmed into storage by the Experiment through the Spacecraft Data Handling Equipment (SDHE).

A further word pair may be programmed by the Experiment from the EDHE. These two words identify the data source, the time of data entry, and the mode of Spacecraft programming operation. This word pair is identified as PC or Program Code word pair.

C. READOUT CONTROL

The readout control portion of the Control Electronics system performs the programming of the output data words, frames and sequences of frames during the stored mode of Spacecraft operation. The selected mode of operation of the WEP determines the sequence of data frames. Fig. VII-4 shows the data frame sequences available for each mode. Both Mode A and Mode B cause six sets of Experiment measurement data to be bracketed by Spacecraft pointing angle data. The PC word pair is also included for identification. The Mode C data sequence is related to the number of grating steps commanded for the Spectrometer grating.

Examination of the WEP readout control logic diagram (Fig. VII-5) will illustrate how the data sequences are generated. When the Mode A control is used, EOC line A initiates a 6-second delay which in turn causes the WEP to send a Repeat Command to the spacecraft. Digital start exposure signals are also sent to each instrument's exposure time generator at the end of this 6-second delay. As a result of the Repeat Command, the Spacecraft data handling enters the SS data into the Spacecraft data storage, and upon completion of this entry gives the WEP a Program Complete signal. The WEP uses this to generate a Repeat Sequence Start command, which causes the EDHE to enter PC data into Spacecraft storage. At completion of PC data entry, a Store Mode Ready signal is sent to the WEP enabling a flip flop controlling the entry of ED data. As each Photometer exposure time generator completes its exposure time, the digital word containing that Photometer's measurement data is stored in the Spacecraft data storage. Upon completion of all four exposures, the ED control flip flop is reset, and a Store Analog signal is sent to the EDHE. The EDHE enters the Experiment Analog (EA) data frame and returns an Analog Cycle Complete signal. This completes one measurement cycle.

The Repeat Experiment signal re-initiates the four Stellar Photometer exposure time generators. After a short delay the Delayed Repeat Experiment signal re-enables the ED flip flop. Each photometer Exposure Complete signal causes its associated digital word to be stored, yielding the second frame of ED data. The completion of all four photometer exposures causes the ED flip flop to be reset and the second Store Analog signal to be generated. This causes the second set of EA data to be stored, thus completing measurement cycle number 2. While in Mode A, this complete ED, EA operation repeats until six measurement cycles have been taken. Upon reaching measurement cycle count number 6, further Repeat Experiments are inhibited, a Repeat Command is generated (entering SS data into storage) and the Program Complete signal is inhibited. This latter action prohibits continuation of the data readout sequence, and thus ends the Mode A entry of data into storage.

An alternate operating procedure is available as an option in Mode A, referred to as filter cycling. It is similar to the above except that all Stellar filter wheels are stepped one position at the end of each readout, so that the six successive measurement cycles are taken on the following sequence of filters for all Stellars: 1, 2, 3, 4, 5 and 1. In this manner a complete spectral scan, using all Stellar filters, can be made on a single target within a relatively short period of time. The command codes necessary to initiate filter cycling are shown in Fig. VII-1.

When a Mode B command is transmitted readout control operation is identical to that of Mode A with two notable exceptions. The first is that a separate six second delay circuit is used to initiate the start of all exposure time generators, and the start of the readout sequence. The second difference is that the Nebular Exposure Complete signal controls the time of the Store Digital Word number 1 and number 2 signals. If the Digital Word numbers 3 and 4 have not already been stored by a Stellar Photometer 3 or 4 exposure complete, the Nebular exposure complete signal causes these words to be entered as well as words 1 and 2. The logic was set up this way since (a) all Nebular photometer information is contained only in digital words 1 and 2, and (b) since the Nebular is the prime instrument of interest in Mode B, it should control the maximum timing of each complete measurement cycle. The mechanization of this readout control logic is obtained through setting a flip flop in the Nebular Mode Register whenever a Nebular command is issued. This flip flop is set by bit 30 on EOC line B and reset by the leading edge of the Command Enable signal.

When operating the Scanning Spectrometer using Mode C the same Readout Control logic of Fig. VII-5 is used. In this case, the readout sequence and start of all exposures is initiated by a Spectrometer start signal. This signal is time coincident with the transmission of a Mode C command since no 6-second delay for filter operations is required as is the case in the Stellar and Nebular Photometers. Bit number 31 off EOC line C command codes provides this Spectrometer start signal. Bit number 32 on the same EOC line C causes a flip flop to be set in the Spectrometer mode register. This flip flop allows the Spectrometer exposure complete to control the entry of digital words 3 and 4 into storage and also allows the Spectrometer exposure to control the maximum time of each measurement cycle. Further, when this Spectrometer mode flip flop is enabled, measurement cycle count number 6 is prohibited from accomplishing its normal function. This results in measurement cycles continuing until both the Spectrometer mode flip flop has been reset and the measurement cycle counter has reached a count of six again. The reset of the Spectrometer mode flip flop is accomplished when the Spectrometer reaches its commanded number of steps or when the Spectrometer grating reaches either end of travel. The result of the reset of the Spectrometer mode flip flop is to set the readout control back into Mode A for the remaining measurement cycles. Since the measurement cycle counter is a three-stage binary counter with a total count capability of 2^3 or 8, it is possible for a maximum of seven Mode A measurement cycles to occur following the end of Mode C controlled measurement cycles. Since during Mode C the measurement cycle counter counts each Spectrometer measurement cycle and for each Spectrometer measurement cycle there is one Spectrometer grating step, the exact number of total measurement cycles to expect can be determined from a knowledge of the number of grating steps taken (i.e., either the number of grating steps commanded or the number to its end of travel.)

One programming restriction on the spectrometers does exist in order to avoid garbling the Mode A data and the SS data following the Mode C controlled data. This restriction is to avoid commanding the Spectrometer to step a number of steps which will leave the measurement cycle counter at a count of 6 or 7 when mode switching occurs. The Spectrometer does not control the readout for its last step and therefore the number of Mode C measurement cycles is one less than the number of Spectrometer steps. Typical quantities of steps to be avoided are thus 7 and 8, 15 and 16, 23 and 24, 31 and 32, 39 and 40, etc. This number of steps is thus 8 x n and 8 x n-1, where n is any integer from 1 to 12, inclusive.

A further word of explanation is perhaps in order regarding the number of steps the Spectrometer will take for particular input step commands. It may be observed from the coding chart for Mode C, Fig. VII-1 that to step the grating to any position, a binary number must be inserted equal to 128 minus the desired number of steps. Thus, if 3 steps are required, a binary number of 125 would be inserted. This will yield spectrometer- or Mode C-controlled readouts on the first and second grating positions away from its original position. The Spectrometer will go to the third position but Mode A will control the readout for this position. If all ones were to be entered in the grating step positions bit (a binary number equivalent to 127), this would cause one step to be taken with no Mode C-controlled readouts. The entry of all zeroes would inhibit any grating steps, and readouts would also be under Mode A control.

It may be determined from the readout control logic diagram of Fig. VII-5 that the readout control operates in Mode D just as in Mode A provided that bit number 3 is included in a Mode D command. If bit number 3 is not included, the appropriate commanded aperture and collimation changes will occur, but no readout will be obtained.

A portion of the Experiment Analog (EA) Mode is shown on the readout control logic diagram, Fig. VII-5. The logic for this mode consists of an AND gate for bit time 30 and the EA Mode code line, the output of which sets an EA Mode flip flop. The set output of the EA Mode flip flop is AND gated with a 1 pps timing signal which, in turn, causes a Store Analog signal to be repetitively transmitted to the Spacecraft EDHE at the 1 second rate. The EA Mode flip flop is reset only by a new Command Enable signal. The logic for the EA Mode was set up such that it bypasses almost all of the readout control logic. It thus provides a backup means of obtaining significant data should major portions of the readout control fail.

A summary of the controlling instrument exposure time for readout of each digital word for different modes of operation is presented in Fig. VII-6. The readout control logic shows that whenever <u>any</u> one exposure time generator gets a start exposure command, so do all exposure time generators. Consequently, correct digital data <u>may</u> often be obtained for instruments normally associated with another mode. In general, digital data for the non-primary instrument will be correct if its exposure time is equal to or less than the exposure time for the primary instrument controlling readout of its digital word. The Scanning Spectrometer digital exposure will run its most recently programmed digital exposure correctly regardless of repetitive Start Exposures caused by primary mode measurement cycles. Consequently, the digital measurement appearing for the Scanning Spectrometer when operating in a mode other than Mode C may represent data caught "on the fly" rather than correct measurement data for the exposure time indicated in the digital status. Thus, successive measurement cycles with timing intervals less than the exposure time of the Scanning Spectrometer should illustrate a buildup of Spectrometer data towards the limit of its preset exposure time. A similar situation does <u>not</u> exist for the Stellar and Nebular photometers when in their non-primary modes. For these instruments, receipt of additional Start Exposures during a previous exposure may stop the original exposure, but not restart the exposure until the next start exposure. Careful analysis of sequential sets of measurement cycle digital data can generally reveal what the non-primary instrument digital measurement data truly represents. However, when the non-primary instrument digital exposure exceeds that of the primary instrument, extreme care must be used in the data analysis.

The time between start of non-filter cycling exposures (and thus the start of successive measurement cycles) is dependent on the mode of operation and thus upon the exposure time commanded for the primary instrument of the selected mode. This time between start of non-filter cycling exposures is as follows:

a. Time between start of successive 1/8 second exposures is 1 second (where all exposures of the mode of operation are set for 1/8 second).

b. Time between start of successive 1 second exposures is 2 seconds.

c. Time between start of successive 8 second exposures is 9 seconds.

d. Time between start of successive 64 second exposures is 65 seconds.

The analog data for each instrument is always correct and in agreement with the gain status indicated, regardless of the mode of operation. The time between successive samples of analog data in any mode other than the EA mode, is the same as the time between start of successive exposures.

D. TYPICAL SINGLE OBSERVATION PROCEDURES

In order to summarize the observational procedure utilized in controlling the WEP, a discussion of the programming for a typical Stellar Photometer observation is presented. To simplify this discussion, several assumptions are made:

1. The Spacecraft is in orbit appropriately oriented on the selected star to be observed and using selected guide stars as a reference in inertial space.
2. The Spacecraft is within line of sight of a ground control station, and the Spacecraft telemetry receiver has been commanded on.
3. It is desired to enter commands into Spacecraft storage for subsequent WEP usage (i.e., the Stored Mode of Operation).
4. Appropriate operational constraints discussed in a subsequent section have previously been observed.

Commands are issued to the Spacecraft in 32 bit word pairs. The first of these is utilized by the Spacecraft. The second command word is entered into Spacecraft storage (in the Stored Mode) and at the proper time will be presented to the Experiment on an Experiment Operation Code (EOC) line.

The structure of the first command word is shown in Fig. VII-7 as part of the OAO Command Format. Since a stored command word is desired, the real time mode control bit number 3 is selected as a binary ZERO. Bit number 4, 5, and 6 are selected binary ONE, ONE, ZERO, respectively, to indicate the second word is an <u>Experiment</u> operation code. Bits nine through eighteen are selected for the time after clock reset at which it is desired to issue the second command word from storage to the Experiment. Zero time has presumably been reset during the line-of-sight communication with the ground control station. Stored commands can be sent at any one-minute increment from time zero. Consequently, with 10 binary bits available, 2^{10} or 1024 minutes are available. Bits 19 through 26 contain the address of the place in command storage that the command words are to be sent. These eight bits represent any storage address of the command storage capacity of 2^7 or 128 command word pairs. Bits 27 through 31 provide for the selection of the Experiment Operation Code line over which the second command word is to be sent from storage to the Experiment. These five binary bits select one of the 2^5 or 32 code lines available. Only 13 of these 32 are available for the WEP. It should be noted that GAEC Spacecraft EOC line numbers are not the same as the WEP EOC line numbers. The conversion between EOC line numbering systems is given at the left edge of Fig. VII-1. Care must be taken in programming to assure proper GAEC equivalent line numbers are used for the EOC lines designated within this description.

Since it is hypothesized as desirable to make a complete spectral observation on a single star, Mode A is selected. Command inputs to Mode A Stellar Photometer control circuits must be made over WEP EOC lines 1, 2, or 3, as shown in Fig. VII-1. Let it be further assumed that no anticipated stellar spectral intensity variation is anticipated over an observation time period of approximately 20 minutes, that redundant storage of each measurement cycle is desirable, and that it is desirable to match digital exposure time (which is also analog gain) to some roughly anticipated intensity level for each spectral band (filter position) to be observed. Mode A operation without automatic filter cycling is best adapted to each of these conditions. The OAO-WEP Command Codes of Fig. VII-1 further illustrate that each of four Stellar Photometers may be commanded to any one of their five filter wheel positions. Reference is made to Fig. II-5 for the nominal wavelength passband available at each filter wheel position. The sequence of wavelength selection is left to the option of the Experimenter. However, it is considered good practice to sequence all filters in the same numerical order, e.g., 1, 2, 3, 4, 5, and 1. This practice is established largely by a desire not to have more than one dark slide or more than one calibration source obscuring the optical path at any one time. Thus, a failure of the control system would still allow significant measurement data to be obtained. No dark or calibration slides are present in any Photometer's filter position number one, since (a) it is a more probable position for certain types of equipment failures, (b) it is a position for which data is more often taken, and (c) it makes a significant data position in which to leave the Stellar Photometers when another instrument (or mode) is being utilized.

Having selected the sequence of filters, one must also select the exposure times for each position. Recalling that 1/8 second is the shortest digital exposure time, and thus the lowest analog gain, an estimate of the relative intensity of the observed stellar object must be made for the spectral band of observation. The Experimenter would presumably make use of enclosed calibration data, relative magnitude data of the star, and any past UV observational data available on this object or anticipated similar objects. Barring any of the latter, a certain amount of trial and error would appear required.

A shorthand code has been set up for designating exposure times and filter positions. "E" designates exposure time and 1, 2, 3, and 4 designate respectively, 1/8, 1, 8, and 64 seconds. "F" designates filter position and 1, 2, 3, 4, and 5 designate the five filter positions. Thus, a typical second word OAO-WEP command for the conditions previously described would be written:

Mode A, non-cyclic

Ph. 1 E2 F1
Ph. 2 E3 F1
Ph. 3 E2 F1
Ph. 4 E3 F1

This second command word would be coded by means of examination of Fig. VII-1 WEP code chart. The particular code for the selected command is shown in Fig. VII-8 along with the set of anticipated data which would result from this command.

An estimate of the time required for the execution of this command must be made. A time sequence chart for this command is shown in Fig. VII-9. Since all data from this command will be stored in less than two minutes, it is safe to issue a second word pair at the second minute increment following the first command word pair. The first command word (of the second pair) would be coded for the next available Spacecraft command storage position. It would include a time tag for execution of the second WEP Command Word at the second minute increment after the issuance of the first WEP Command. A typical second WEP observation command would be

Mode A, non-cyclic

Ph. 1 E3 F2
Ph. 2 E2 F2
Ph. 3 E2 F2
Ph. 4 E3 F2

This command would be coded as shown in Fig. VII-10. The anticipated output is also shown in this figure. Again, an estimate of the time required for the execution of this command is necessary. Since the maximum exposure time is again E3 or 8 seconds, the total time will be the same as in the first sequence. Consequently, the next word pair should not be issued until after a 2-minute wait. Typical command word pairs necessary to complete the hypothesized complete stellar spectral observation are as follows:

Word Pair 3

First Word: stored, EOC line 1, Execute 2 minutes after Pair 2, next available storage address.

Second Word: Mode A non-cyclic

Ph. 1 E1 F3
Ph. 2 E3 F3
Ph. 3 E3 F3
Ph. 4 E3 F3

Word Pair 4

First Word: Stored, EOC line 1, Execute 2 minutes after Pair 3, next available storage address.

Second Word: Mode A non-cyclic

Ph. 1 E3 F4
Ph. 2 E3 F4
Ph. 3 E3 F4
Ph. 4 E3 F4

Word Pair 5

First Word: Stored, EOC line 1, Execute 2 minutes after Pair 4, next available storage address.

Second Word: Mode A non-cyclic

Ph. 1 E3 F5
Ph. 2 E2 F5
Ph. 3 E1 F5
Ph. 4 E3 F5

<u>Word Pair 6</u>

First Word: Stored, EOC line 1, Execute 2 minutes aft[e]

Pair 5, next available storage address.

Second Word:

Ph. 1 E2 F1
Ph. 2 E1 F1
Ph. 3 E2 F1
Ph. 4 E1 F1

This would complete the Stellar Photometer Spectral observation. Approximately 15 minutes would have elapsed following the issuance o[f] first command word. Each command would have entered 184 25-bit [d] words into data storage (64 SS, 2 PC, 6 sets of 4-digital and 5 analog making 54 experiment words, and another 64 SS words in that order). total number of data words stored for these six input command word [p] would thus be 1104.

Since some time in orbit is remaining and some data storage [s] is left in the 4096 redundant data word storage, the Experimenter ma[y] desire to make a backup Scanning Spectrometer reading on the same [s] object. The Scanning Spectrometer is controlled in Mode C. The [c] coding capabilities for Mode C are shown in Fig. VII-1. WEP code 9, 10, <u>or</u> 11 may be arbitrarily selected. The following assumptions be made for the programming of this observation:

1. The far UV is of primary interest and therefore Spectrometer No. 2 should be selected.

2. It has been ascertained from previous status data that the desired slit width is in place.

3. Appropriate analysis had shown that a complete sweep of 100 steps of the Spectrometer at a 64-second exposure would take over 100 minutes, which, during a portion of the orbit, would align the instruments looking back at the sunlit earth. This would be contrary to the subsequently discussed design constraints. Thus, an 8-second exposure is selected which can complete the 100 steps in 15 minutes. The 8-second gain is not the highest but will be presumed satisfactory as a first pass and in view of the backup nature of this Spectrometer observation.

4. Previous observational data or programmed commands have been utilized to determine that Spectrometer No. 2 is at its 1000Å limit. To proceed towards 2000Å, a Reverse Command must be given.

5. Since it is desired to step the grating to the 2000Å limit, through all available 100 steps, a grating step command of 100 or greater must be entered via Mode C. Under these conditions, the Spectrometer will automatically stop upon reaching its end of travel.

The particular second command word to accomplish these hypothesized objectives is shown in Fig. VII-11. The total time for the 100 steps would be 15 minutes at a 9 seconds per step rate (8-seconds exposure plus one intervening second). The number of data words stored would be 1048. (64 SS, 2 PC, and I. D., 100 x 9 analog and digital words via Mode C, 18 analog and digital words via Mode A, and 64 SS, all in that order.)

Thus, a total of 30 minutes orbit time and 2152 data storage words would have been used by the seven experiment commands. Provided that none of the design constraints are broken, the Experimenter might repeat the same Mode C operation using Spectrometer No. 1 to fill out the backup of the complete UV coverage. This would take 15 more minutes and another 1048 words, using up a total orbit time of 45 minutes and data storage capacity of 3200 data words. This would complete a typical single observation using the WEP.

Subsequent command word pairs would likely be used to slew the Spacecraft to a new star. The first command word would be identical to the first word used for WEP commands except that different operation code bits would direct the second word to the appropriate Spacecraft subsystem. The control bits associated with selection of the EOC line number would also assume a different meaning dependent upon the operation code selected. The second command word bit control function is also completely dependent upon the operation code or Spacecraft subsystem selected. The detailed programming of these Spacecraft subsystems is beyond the scope of this

Experiment Description. Reference should be made to the OAO Spacecraft Handbook, or to a Spacecraft Programming Interface Document which is in preparation but is not available at the time of this writing. The currently anticipated OAO second command word format for Spacecraft subsystems is included in Fig. VII-7 for general information.

E CONSTRAINTS ON THE USE OF THE WEP

A number of constraints are placed on the operational use of the WEP integrated with the Spacecraft. A brief listing and discussion of these are presented in order that the Experimenter may avoid potential problems.

1. WEP Power Application

The application of 28 vdc power to the WEP is controlled by command to one of the Spacecraft subsystems. This power should not be applied during launch because the WEP subsequently passes through an intermediate vacuum, and there exists the possibility of corona discharge off the high voltage power lines. This would not necessarily be damaging but should be avoided for safety.

2. Readout Enable

When power is first applied to the WEP, it is possible some unwanted data readouts will occur and also possible some wanted data read outs will not appear. Shortly after WEP power application, it is good practice to issue a Mode B, E1, F1 command including a Readout Enable ("1" in bit 24). This will set up the WEP so that it is capable of programm data into storage. Up to 184 data words and 1 minute of time may be wasted as a result of this command, but it may prove worthwhile to precede each major WEP observational sequence with this setup command. It is noted that a readout inhibit bit is available in Mode B for use when other experiments are taking data, when real time synchronous data is being taken from the WEP under EDHE control, and in potential failure conditions where it may be desired to assure that the WEP is not causing data entry into storage. Entry of data into storage from more than one source at the same time will cause garbled data to be stored.

3. Phototube Protection

It has been anticipated that damage to the phototubes may be caused by excessive illumination. A sunshade is provided on the Spacecraft which is designed to automatically start to close whenever the sun comes within 45° of the optical axis. The rate of closure of the sun shade and the slew rate of the Spacecraft are such that the shade should be closed when the sun is within 30° of the optical axis. The shade will, of course, shield the WEP from both the sun and any desired phenomena to be observed when the shade is in the closed position. This precludes the Experimenter from observing a large number of objects located near the sun. The exact level of phototube light sensitivity to damage has not been determined. Consequently, it may be found that the WEP should not be pointed at the sunlit earth or the moon. Presumably, these questions will be shortly resolved, but a check by any new Experimenters on these potential time oriented pointing limitations should be made. As a further pointing limitation, it is noted that the capability of jettisoning the sun shade is present in case of failure of the sunshade to open. In case the sunshade has been jettisoned, great care must be taken to not slew the Spacecraft across the optical line to the sun.

4. Filter Cycling

The filter wheel drive mechanism has been designed to have a useful life quite sufficient to permit a year's operation with as many filter wheel cycling mode measurements as might reasonably be expected, and life tests have verified that this design is conservative. However, it would be a wise precaution to not leave the Stellars in the filter cycling mode indefinitely and without purpose while some other set of measurements are being made (e.g., a long series of Spectrometer measurements). Therefore, it is recommended that the Stellars be left in the non-cycling mode when changing from a Mode A measurement to Modes B or C.

5. EDHE Setup for WEP

When the WEP is to be used in its normal stored mode of operation (i.e., data is transmitted to Spacecraft storage via EDHE), a particular data handling command word must precede any WEP command to properly set up the EDHE Spacecraft subsystem. The Data Handling Command Word pair must set the EDHE for Store Mode (as vs Real Time modes) and Asynchronous Mode In Store Mode (as vs Lockout Mode or other Real Time Mode selections). Reference to Fig. 4-5 of the 15 April 1963 revision to the OAO Spacecraft Handbook reveals that the second word of the Data Handling word pair must thus have binary ONEs in bit positions 1, 2, 4, 8, and 15. This same handbook describes on pages 4-26 to 4-27 programming restrictions regarding use of the EDHE with other Spacecraft subsystems. This information is pertinent particularly where it is desired to use the WEP in real time when in line-of-sight with the ground station. Presumably, the total real time available will only average 10 minutes each orbit. Consequently, what with other requirements for this time period, little time would be left for a WEP real time operation. These other requirements include establishing contact, setting up real time modes, turning on appropriate Spacecraft transmitters, emptying Spacecraft data storage, entering new commands in Spacecraft command storage, resetting time zero, perhaps taking data from Experiments only capable of real time operation, etc.

6. SDHE Setup

Care must be taken that the SDHE Spacecraft subsystem has been previously set up (via a data handling command word pair) in the proper condition for use with the WEP. This requires selection of Stored Mode (as vs Real Time) and one output data frame (as vs continuous, repetitive rate, or four data frames). Reference to Fig. 4-7 of the 15 April 1963 revision of the Spacecraft Handbook will show that the second word of the data handling command word pair should have a binary ONE in bit positions 1, 2, 3, and 8. Bit positions 15, 16, 17, and 18 must be binary ZERO.

Fig. 4-6 of the Handbook indicates that words 1 through 26 will include identification, time, and gimbal pointing angle data which are the main items of Experimenter interest. Pages 4-43 and 4-44 of the same issue of the Handbook present SDHE programming restrictions.

7. Garbled Data

Garbled data are herein defined as any data sets which do not follow the prescribed format. Garbled data from the WEP may occur under the following conditions:

a. When the Experiment power is applied.

b. When the ±10 v power supply is switched.

c. When the University of Wisconsin clock is reset.

d. When the readout inhibit bit is removed via readout enable bit.

e. When a Scanning Spectrometer is commanded to a position or limit which will leave the WEP measurement cycle counter at a count of 6 or 7 when mode switching occurs. In this case, only the data following the mode switching will be garbled.

MODE A

	COMMAND	REGISTER CLEAR	FILTER CYCLE	STELLAR #1 EXPOSURE TIME (SEC)				STELLAR #1 FILTER WHEEL POSITION					STELLAR #2 EXPOSURE TIME (SEC)				STELLAR #2 FILTER WHEEL POSITION					STELLAR #3 EXPOSURE TIME (SEC)				STELLAR #3 FILTER WHEEL POSITION					STELLAR #4 EXPOSURE TIME (SEC)				STELLAR #4 FILTER WHEEL POSITION				
	BIT NO.	3	4		5	6	7		8	9	10	11		12	13	14		15	16	17	18		19	20	21		22	23	24	25		26	27	28		29	30	31	32
E.O.C. LINES 1,2,3 (GAEC 7,26,11)	CODES	MUST BE 1	"0" = REMAIN AT ONE FILTER POS "1" = CYCLE FILTER WHEELS	1/8	0	0	1	1		0	0	0	1/8	0	0	1	1		0	0	0	1/8	0	0	1	1		0	0	0	1/8	0	0	1	1		0	0	0
					1	1	0			1	1	1		1	1	0			1	1	1		1	1	0			1	1	1		1	1	0			1	1	1
				1	0	1	0	2		1	0	0	1	0	1	0	2		1	0	0	1	0	1	0	2		1	0	0	1	0	1	0	2		1	0	0
					1	0	1		1	0	1	1		1	0	1		1	0	1	1		1	0	1		1	0	1	1		1	0	1		1	0	1	1
				8	0	0	0	3		1	1	0	8	0	0	0	3		1	1	0	8	0	0	0	3		1	1	0	8	0	0	0	3		1	1	0
					1	1	1		1	0	0	1		1	1	1		1	0	0	1		1	1	1		1	0	0	1		1	1	1		1	0	0	1
				64	0	1	1	4	0	0	1		64	0	1	1	4	0	0	1		64	0	1	1	4	0	0	1		64	0	1	1	4	0	0	1	
					1	0	0		1	1	0	1		1	0	0		1	1	0	1		1	0	0		1	1	0	1		1	0	0		1	1	0	1
								5	1	0	1	0					5	1	0	1	0					5	1	0	1	0					5	1	0	1	0
									0		0	1						0		0	1						0		0	1						0		0	1
	CODES FOR PROPER FILTER CYCLE OPERATION	1	1	ABOVE					0	0	0	0	ABOVE					0	0	0	0	ABOVE					0	0	0	0	ABOVE					0	0	0	0
									1	1	1	1						1	1	1	1						1	1	1	1						1	1	1	1

MODE B

	COMMAND	REGISTER CLEAR	NEBULAR PHOTOMETER EXPOSURE TIME (SEC)				NEBULAR PHOTOMETER FILTER WHEEL POSITION					NEBULAR FIELD STOP	READOUT INHIBIT		E.D. READOUT MODE
	BIT NO.	4		6	8	10		12	14	16	18	20	22	24	30
E.O.C. LINES 4,5,6 (GAEC 8,25,12)	CODES	MUST BE 1 FOR NEBULAR PHOT. OPERATION MUST BE 0 FOR READOUT INHIBIT	1/8	0	0	1	1	0	0	0	0	1 = CHANGE POSITION	1 = INHIBIT READOUT	1 = ENABLE READOUT	MUST BE 1
				1	1	0		1	1	1	1				
			1	0	1	0	2		1	0	0				
				1	0	1		1	0	1	1				
			8	0	0	0	3		1	1	0				
				1	1	1		1	0	0	1				
			64	0	1	1	4	0	0	1					
				1	0	0		1	1	0	1				
							5	1	0	1	0				
								0		0	1				
							6	1	0	0	0				
								0	1	1	1				

MODE C

E.O.C. LINES 9, 10, 11 (GAEC 9,24,28)	COMMAND	REGISTER CLEAR	SLIT POSITION		SPECTROMETER SELECTOR	SPECTROMETER EXPOSURE TIME	GRATING STEP DIRECTION	GRATING STEP TO ANY POSITION							SPEC. START	E.D. READOUT MODE
			#1	#2				64	32	16	8	4	2	1		
	BIT NO.	3	5	7	9	11	13	17	19	21	23	25	27	29	31	32
	CODES	MUST BE 1	1 = CHANGE POSITION 0 = DONT		1 = SPEC #1 0 = SPEC #2	0 = 8 SEC. 1 = 64 SEC.	0 = FORWARD 1 = REVERSE	INSERT BINARY NO. EQUAL TO 128 MINUS DESIRED NO. OF STEPS FROM LAST POS.							MUST BE 1	

MODE D

E.O.C. LINES 7,8 (GAEC 10,23)	COMMAND	F.W. TIME DELAY START	STELLAR #1 COLLIMATION				STELLAR #1 FIELD STOP	STELLAR #2 COLLIMATION				STELLAR #2 FIELD STOP	STELLAR #3 COLLIMATION				STELLAR #3 FIELD STOP	STELLAR #4 COLLIMATION				STELLAR #4 FIELD STOP
			* $-Y_c$	$+Y_c$	$-Z_c$	* $+Z_c$		* $+Z_c$	$-Z_c$	$-Y_c$	* $+Y_c$		* $+Y_c$	$-Y_c$	$+Z_c$	* $-Z_c$		* $-Z_c$	$+Z_c$	$+Y_c$	* $-Y_c$	
	BIT NO.	3	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	23	25	31	32	5
	CODES	MUST BE 1	1 = CHANGE POSITION, EACH 4-BIT COLLIMATION COMMAND SHOULD CONTAIN ONLY ONE 1																			

* DIRECTION TO ENERGIZE LIMIT SWITCH

POWER SUPPLY SWITCHING MODE				
E.O.C. LINE 13 (GAEC 27)	P.S. COMMANDED	±10VDC	±15VDC	H.V.
	BIT NO.	24	26	28
	CODE	1 = SWITCH SUPPLIES		

NOTE: FOR CONSISTENCY OF CODING, BITS NOT SPECIFIED SHOULD BE 0.

EXPERIMENT ANALOG MODE: E.O.C. LINE 12 (GAEC 29) BIT NO. 30: 1 STARTS EA MODE OPERATION.

FIG. VII - 1 OAO WEP COMMAND INPUT CODES

	ANALOG DATA FUNCTIONS
1	STELLAR PHOTOMETER #1
2	STELLAR PHOTOMETER #2
3	STELLAR PHOTOMETER #3
4	STELLAR PHOTOMETER #4
5	NEBULAR PHOTOMETER
6	SCANNING SPECTROMETER #1
7	SCANNING SPECTROMETER #2
8	+10 VDC POWER SUPPLY VOLTAGE
9	−10 VDC POWER SUPPLY VOLTAGE
10	+15 VDC POWER SUPPLY VOLTAGE
11	−15 VDC POWER SUPPLY VOLTAGE
12	HIGH VOLTAGE POWER SUPPLY VOLTAGE
13	CONTROL ELECTRONICS TEMPERATURE
14	NEBULAR TOP TEMPERATURE
15	PRIMARY STRUCTURE TEMPERATURE

FIG. VII-2 WEP ANALOG OUTPUT DATA FRAME

<table>
<tr><td>BIT NUMBER</td><td>1</td><td>2 3</td><td>4 5 6 7 8 9 10 11</td><td>12 13 14</td><td>15 16</td><td>17</td><td>18 19</td><td>20 21</td><td>22</td><td>23</td><td>24</td><td>25</td></tr>
<tr><td>GATE NO. 1
(WORD NO. 1)</td><td colspan="2">WORD I.D.
CODES
0 0 0</td><td>STELLAR PHOTOMETER
MEASUREMENT DATA NO. 1</td><td>FILTER
POS. NO. 1</td><td>EXPOSURE TIME
#1</td><td>APERTURE STATUS
#1</td><td>MODE
I.D.</td><td colspan="2">NEBULAR
FILTER
POSITION</td><td colspan="2">NEB.
EXPOS.
TIME</td><td>NEB.
APER.</td></tr>
<tr><td>GATE NO. 2
(WORD NO. 2)</td><td colspan="2">"
0 0 1</td><td>"
NO. 2</td><td>"
NO. 2</td><td>#2</td><td>#2</td><td colspan="6">NEBULAR PHOTOMETER
MEASUREMENT DATA</td></tr>
<tr><td>GATE NO. 3
(WORD NO. 3)</td><td colspan="2">"
0 1 0</td><td>"
NO. 3</td><td>"
NO. 3</td><td>#3</td><td>#3</td><td colspan="6">SCANNING SPECTROMETER
MEASUREMENT DATA</td></tr>
<tr><td>GATE NO. 4
(WORD NO. 4)</td><td>SC.
SP.
I.D.</td><td>"
1 1</td><td>"
NO. 4</td><td>"
NO. 4</td><td>#4</td><td>#4</td><td colspan="2">STELLAR PH.
COLLIMAT.
1 2 3 4</td><td colspan="2">SC. SP.
BAND</td><td>SP. EXP
TIME</td><td>SP. AP.
STATUS</td></tr>
</table>

COLLIMATION STATUS IS 0 WHEN AT A LIMIT SWITCH, OTHERWISE AT 1
APERTURE STATUS: 1 = SMALL APERTURE, 0 = LARGE APERTURE.
SPECTROMETER I.D.: 0 = NO. 2, 1 = NO. 1
SPECTRO EXPOSURE TIME: 0 = 8 SEC. (E1), 1 = 64 SEC. (E2)
PHOTOMETER MEASUREMENT DATA LEAST SIGNIFICANT BIT ON LEFT.

STELLAR FILTER POSITION

NO.	12	13	14
F1	0	1	1
F2	1	0	1
F3	0	0	1
F4	1	1	0
F5	0	1	0

EXPOSURE TIME

NO.	STEL.	15	16
E1	$1/8^s$	1	1
E2	1^s	0	1
E3	8^s	1	0
E4	64^s	0	0
	NEB.	23	24

MODE I.D.

MODE	18	19
A	0	0
B	0	1
C	1	0
D	0	0
E. A.	0	0

NEBULAR FILTER POSITION

NO.	20	21	22
F1	0	1	1
F2	1	0	1
F3	0	0	1
F4	1	1	0
F5	0	1	0
F6	1	0	0

FORWARD STEP DIRECTION

SCANNING SPECTROMETER BAND

SPEC. NO. 1	22	23	SPEC. NO. 2
2000-2500	0	0	1000-1250
2500-3000	1	0	1250-1500
3000-3500	1	1	1500-1750
3500-4000	0	1	1750-2000

FIG. VII-3 WEP DIGITAL OUTPUT FORMAT

					MEASUREMENT CYCLE														
					1		2		3		4		5		6				
MODE A	SS		PC		ED	EA	ED	EA	ED	EA	ED	EA	ED	EA	ED	EA		SS	
MODE B	SS		PC		ED	EA	ED	EA	ED	EA	ED	EA	ED	EA	ED	EA		SS	
MODE C	SS		PC		ED	EA	ED	EA	→ COMMANDED NUMBER OF STEPS OR NO. TO END LIMIT EQUALS THE TOTAL NUMBER OF ED EA FRAMES, THEN SHIFTS TO MODE "A" COMPLETION.										
MODE D	SS		PC		ED	EA	ED	EA	ED	EA	ED	EA	ED	EA	ED	EA		SS	
EXP. ANALOG MODE	EA	EA	EA	EA	EA	EA	EA	→ REPETITIVE UNTIL NEW COMMAND (I PER SECOND)											
POWER SUPPLY SWITCHING						PRODUCES NO OUTPUT													

FIG. VII-4 WEP SEQUENCE OF OUTPUT DATA FRAMES

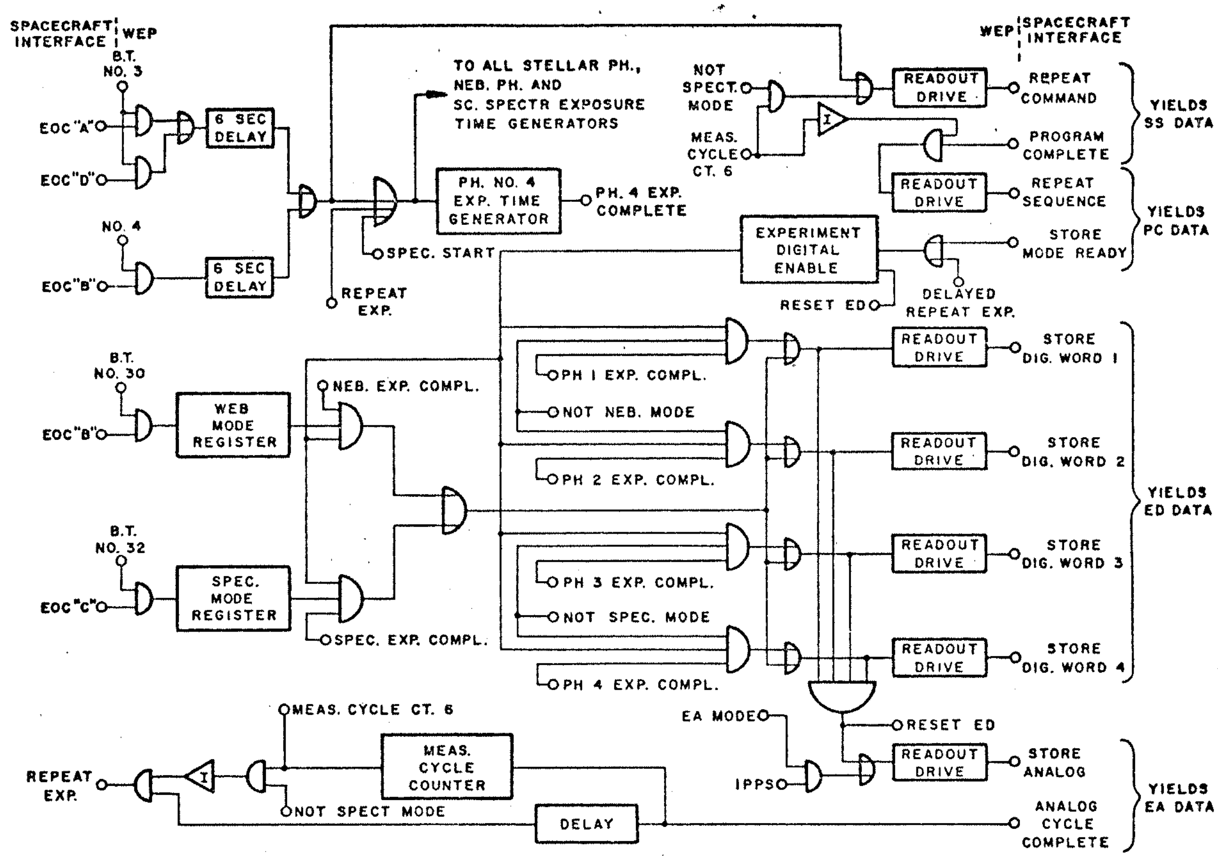


FIG. VII-5 READOUT CONTROL LOGIC DIAGRAM

	MODES A & D	MODE B	MODE C
DIGITAL WORD #1	ST. PH. #1	NEB. PH.	SHORTEST OF SC. SP. AND ST. PH. #1
DIGITAL WORD #2	ST. PH. #2	NEB. PH.	SHORTEST OF SC. SP. AND ST. PH. #2
DIGITAL WORD #3	ST. PH. #3	SHORTEST OF NEB. PH. AND ST. PH. #3	SC. SP.
DIGITAL WORD #4	ST. PH. #4	SHORTEST OF NEB. PH. AND ST. PH. #4	SC. SP.

FIG. VII-6 INSTRUMENT CONTROLLING EXPOSURE TIME AND READOUT OF EACH DIGITAL WORD FOR DIFFERENT MODES OF OPERATION

FIRST COMMAND WORD			
BIT NO.	REAL TIME COMMAND FIRST WORD	STORED COMMAND FIRST WORD	CON
1	REGISTRATION BIT ("1")	REGISTRATION BIT ("1")	REGISTRATIO
2	REGISTRATION BIT ("1")	REGISTRATION BIT ("1")	REGISTRATI
3	REAL TIME MODE CONTROL BIT ("1")	REAL TIME MODE CONTROL BIT ("0")	
4			NOTE
5	OPERATION CODE	OPERATION CODE	
6			
7			
8			STATIC S
9			
10			
11			
12		EXECUTION TIME	
13			
14			
15			
16			
17		(HOB)	NOT
18		(HOB)	
19			
20			
21		ADDRESS	
22			DYNAMIC
23			
24			
25			
26			
27		GIMBAL ANGLE, ATTITUDE OR	
28	GIMBAL ANGLE ATTITUDE OR	EXPERIMENT SELECTION CODE	
29	EXPERIMENT SELECTION CODE		
30			
31			
32			

EXPERIMENT SELECTION CODE					
BIT NO. 27	28	29	30	31	SELECT CHANNEL
0	0	0	0	0	EXPERIMENT OPERATIONAL DATA CHANNEL NO. 1
1	0	0	0	0	EXPERIMENT OPERATIONAL DATA CHANNEL NO. 2
0	1	0	0	0	EXPERIMENT OPERATIONAL DATA CHANNEL NO. 3
0	0	1	1	1	EXPERIMENT OPERATIONAL DATA CHANNEL NO. 29
1	0	1	1	1	EXPERIMENT OPERATIONAL DATA CHANNEL NO. 30
0	1	1	1	1	EXPERIMENT OPERATIONAL DATA CHANNEL NO. 31
1	1	1	1	1	EXPERIMENT OPERATIONAL DATA CHANNEL NO. 32

ATTITUDE SELECTION CODE					
BIT NO. 27	28	29	30	31	SELECTED WHEEL
0	0	0	0	0	PITCH COARSE INERTIA WHEEL
1	0	0	0	0	ROLL COARSE INERTIA WHEEL
0	1	1	1	1	YAW COARSE INERTIA WHEEL

SECOND COMMAND WORD

CONTROL	ADDRESS TRANSFER	EXPERIMENT	GIMBAL ANGLE	
REGISTRATION BIT ("1")	REGISTRATION BIT ("1")	REGISTRATION BIT ("1")	REGISTRATION BIT ("1")	REG
REGISTRATION BIT ("1")	REGISTRATION BIT ("1")	REGISTRATION BIT ("1")	REGISTRATION BIT ("1")	REG
NOTE 4 (A)				
(B)	OPERATION CODE			
(C)				
(D)				
(E)				
STATIC SELECT (F)				SW
(G)			INNER GIMBAL ANGLE	
(H)				
(J)				
(K)	EXECUTION TIME			
(L)				
(M)				
(N)				
		EXPERIMENTER'S		
NOTE 4 (18)	(HOB)	OPERATION CODE		
(19)	(HOB)			
(20)				
(21)				
(22)	ADDRESS			
DYNAMIC SELECT (23)				
(24)			OUTER GIMBAL ANGLE	
(25)				
(26)				
(27)				
(28)	GIMBAL ANGLE,			
(29)	ATTITUDE OR EXPERIMENT			
	SELECTION CODE			

DE
WHEEL
RSE HEEL
RSE HEEL
SE HEEL

GIMBAL ANGLE SELECTION CODE					
BIT NO. 27	28	29	30	31	SELECTED STARTRACKER
0	0	0	0	0	STARTRACKER NO. 1
1	0	0	0	0	STARTRACKER NO. 2
0	1	0	0	0	STARTRACKER NO. 3
1	1	0	0	0	STARTRACKER NO. 4
0	0	1	0	0	STARTRACKER NO. 5
1	0	1	0	0	STARTRACKER NO. 6

OPERATION CODE			
BIT NO. 4	5	6	COMMAND TYPE
0	0	0	GROUND SYNCHRONIZATION
1	0	0	CONTROL
0	1	0	ATTITUDE
1	1	0	EXPERIMENT
0	0	1	ADDRESS TRANSFER
1	0	1	GIMBAL ANGLE
0	1	1	DATA HANDLING
1	1	1	NOT USED

FIG. VII-7 OAO COMMAND FORMAT

SECOND COMMAND WORD

GIMBAL ANGLE	ATTITUDE	DATA HANDLING	GROUND SYNCHRONIZATION
REGISTRATION BIT ("1")	REGISTRATION BIT ("1")	REGISTRATION BIT ("1")	REGISTRATION BIT ("1")
REGISTRATION BIT ("1")	REGISTRATION BIT ("1")	REGISTRATION BIT ("1")	REGISTRATION BIT ("1")
	SWITCH POINT ANGLE		
INNER GIMBAL ANGLE			
	(HOB)		
	SLEW SIGN		GROUND
		DATA HANDLING BITS	SYNCHRONIZATION
			BITS
OUTER GIMBAL ANGLE			
	SLEW ANGLE		
	(HOB)		

RATION CODE
COMMAND TYPE
GROUND SYNCHRONIZATION
CONTROL
ATTITUDE
EXPERIMENT
ADDRESS TRANSFER
GIMBAL ANGLE
DATA HANDLING
NOT USED

NOTES:

1. "1" BINARY ONE
2. "0" BINARY ZERO
3. HOB-HIGH ORDER BIT OF A FIELD
4. (LETTER) (NUMBER) DEFINES ONE OF 156 CONTROL MATRIX OUTPUTS.
5. ▨ INFORMATION CONTAINED IN THIS BIT IS NOT SPECIFIED FOR PPDS/PSSC EQUIPMENT OPERATION.

SAMPLE SINGLE OBSERVATION PAGE 1

U. W. COMMAND LINE 1 TIME < 2 MIN

COMMAND	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
BIT No	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

WORD No

1-64	SPACECRAFT STATUS FRAME (SS)																									
65-66	PROGRAM CODE WORDS (PC)																									
	BIT No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
67	EXPERIMENT	0	0	0	--	--	--	--	--	--	--	--	0	1	1	0	1	1	0	0	NO CHANGE					
68	DIGITAL	0	0	1	--	--	--	--	--	--	--	--	0	1	1	1	0	1	--	--	--	--	--	--	--	--
69	(ED) DATA	0	1	0	--	--	--	--	--	--	--	--	0	1	1	0	1	1	--	--	--	--	--	--	--	--
70	FRAME		1	1	--	--	--	--	--	--	--	--	0	1	1	1	0	1	N	O	CHANGE					
71-75	ANALOG DATA SET																									
76		0	0	0	--	--	--	--	--	--	--	--														
77	SAME AS	0	0	1	--	--	--	--	--	--	--	--							--	--	--	--	--	--	--	--
78	ED ABOVE	0	1	0	--	--	--	--	--	--	--	--							--	--	--	--	--	--	--	--
79			1	1	--	--	--	--	--	--	--	--														
80-84	ANALOG DATA SET																									
85		0	0	0	--	--	--	--	--	--	--	--														
86	SAME AS	0	0	1	--	--	--	--	--	--	--	--							--	--	--	--	--	--	--	--
87	ED ABOVE	0	1	0	--	--	--	--	--	--	--	--							--	--	--	--	--	--	--	--
88			1	1	--	--	--	--	--	--	--	--														
89-93	ANALOG DATA SET																									
94		0	0	0	--	--	--	--	--	--	--	--														
95	SAME AS	0	0	1	--	--	--	--	--	--	--	--							--	--	--	--	--	--	--	--
96	ED ABOVE	0	1	0	--	--	--	--	--	--	--	--							--	--	--	--	--	--	--	--
97			1	1	--	--	--	--	--	--	--	--														
98-102	ANALOG DATA SET																									
103		0	0	0	--	--	--	--	--	--	--	--														
104	SAME AS	0	0	1	--	--	--	--	--	--	--	--							--	--	--	--	--	--	--	--
105	ED ABOVE	0	1	0	--	--	--	--	--	--	--	--							--	--	--	--	--	--	--	--
106			1	1	--	--	--	--	--	--	--	--														
107-111	ANALOG DATA SET																									
112		0	0	0	--	--	--	--	--	--	--	--														
113	SAME AS	0	0	1	--	--	--	--	--	--	--	--							--	--	--	--	--	--	--	--
114	ED ABOVE	0	1	0	--	--	--	--	--	--	--	--							--	--	--	--	--	--	--	--
115			1	1	--	--	--	--	--	--	--	--														
116-120	ANALOG DATA SET																									
121-184	SPACECRAFT STATUS FRAME																									

TOTAL TIME IN SPACECRAFT MINUTES TO GENERATE ALL DATA

U. W. LINE	1	2	3	4	5	6	7	8	9	10	11	12	13
GAEC LINE No	7	26	11	8	25	12	10	23	9	24	28	29	27
OCTAL GAEC LINE No	06	31	12	07	30	13	11	26	10	27	33	34	32

ALL BLANK COLUMNS = DON'T CARE ------------- = DIGITAL DATA

PREPARED BY C.B. DATE

COMMAND MODE A, NON CYCLIC PH1 E2 F1, PH2 E3. F1, PH3 E2 F1, PH4 E3 F1

FIG. VIII - 8

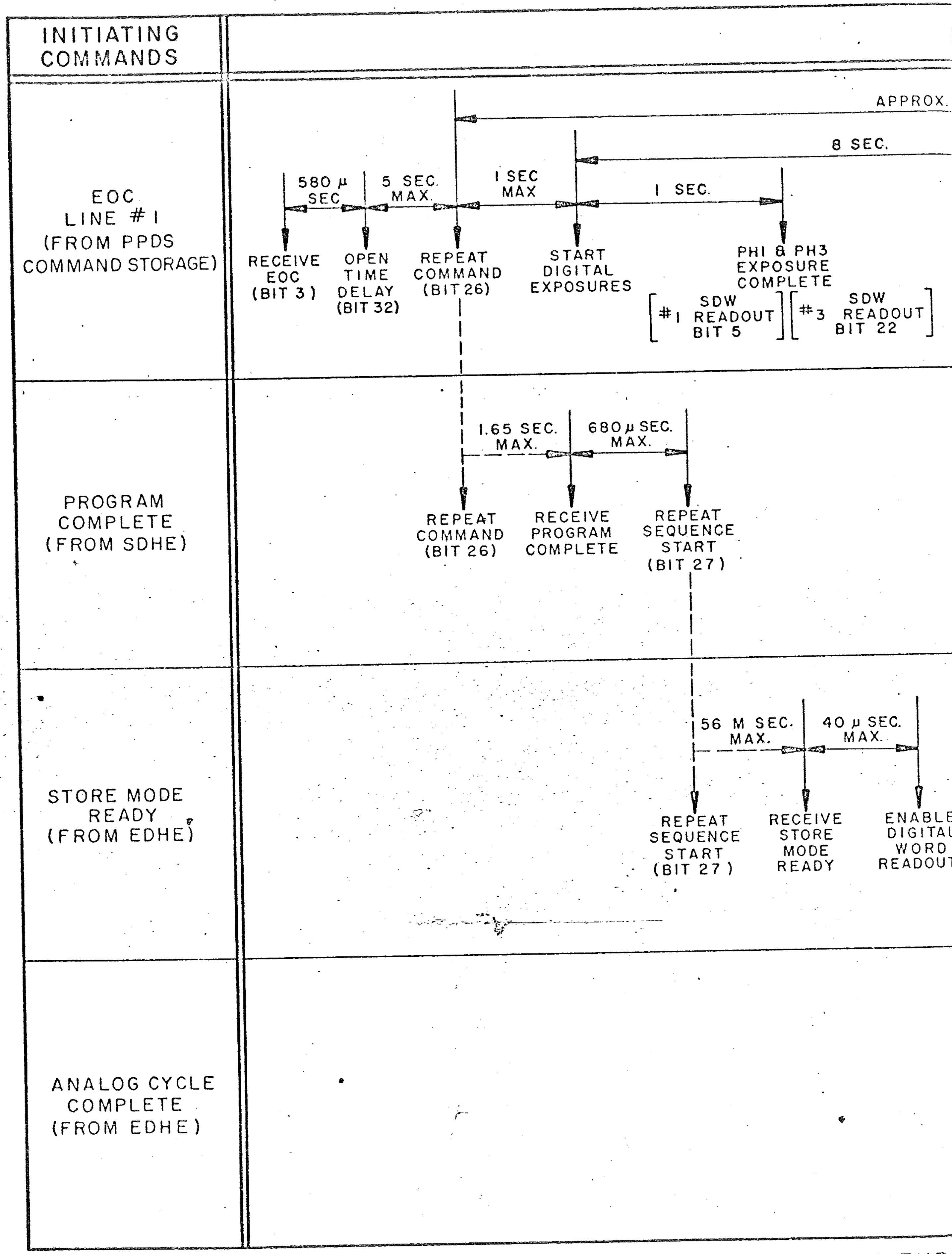

INITIATING COMMANDS
EOC LINE #1 (FROM PPDS COMMAND STORAGE)
PROGRAM COMPLETE (FROM SDHE)
STORE MODE READY (FROM EDHE)
ANALOG CYCLE COMPLETE (FROM EDHE)
APPROX.
8 SEC.
580 μ SEC
5 SEC. MAX.
1 SEC MAX
1 SEC.
RECEIVE EOC (BIT 3)
OPEN TIME DELAY (BIT 32)
REPEAT COMMAND (BIT 26)
START DIGITAL EXPOSURES
PHI & PH3 EXPOSURE COMPLETE
[#1 SDW READOUT BIT 5]
[#3 SDW READOUT BIT 22]
1.65 SEC. MAX.
680 μ SEC. MAX.
REPEAT COMMAND (BIT 26)
RECEIVE PROGRAM COMPLETE
REPEAT SEQUENCE START (BIT 27)
56 M SEC. MAX.
40 μ SEC. MAX.
REPEAT SEQUENCE START (BIT 27)
RECEIVE STORE MODE READY
ENABLE DIGITAL WORD READOUT

FIG. VII-9 TYP

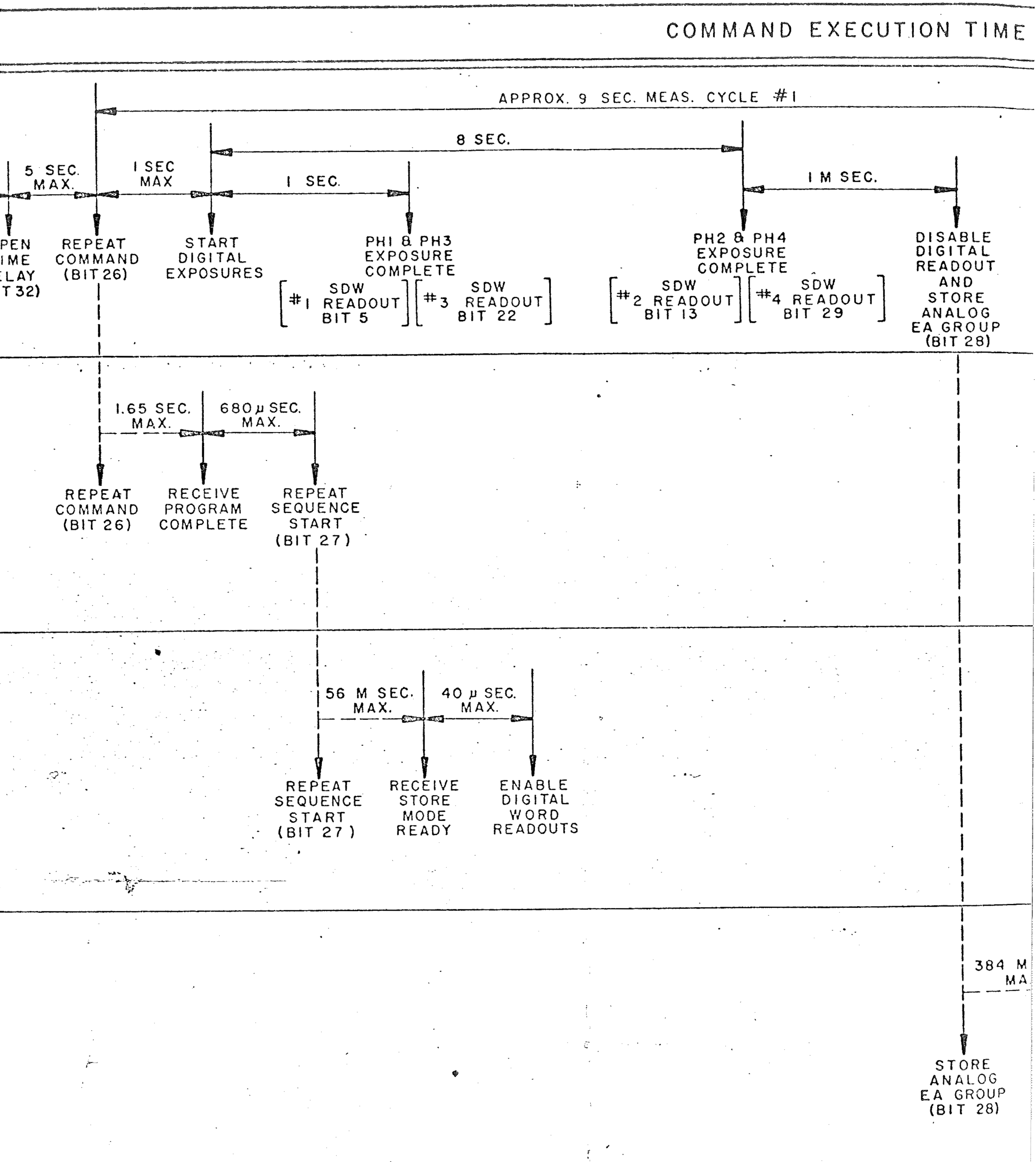
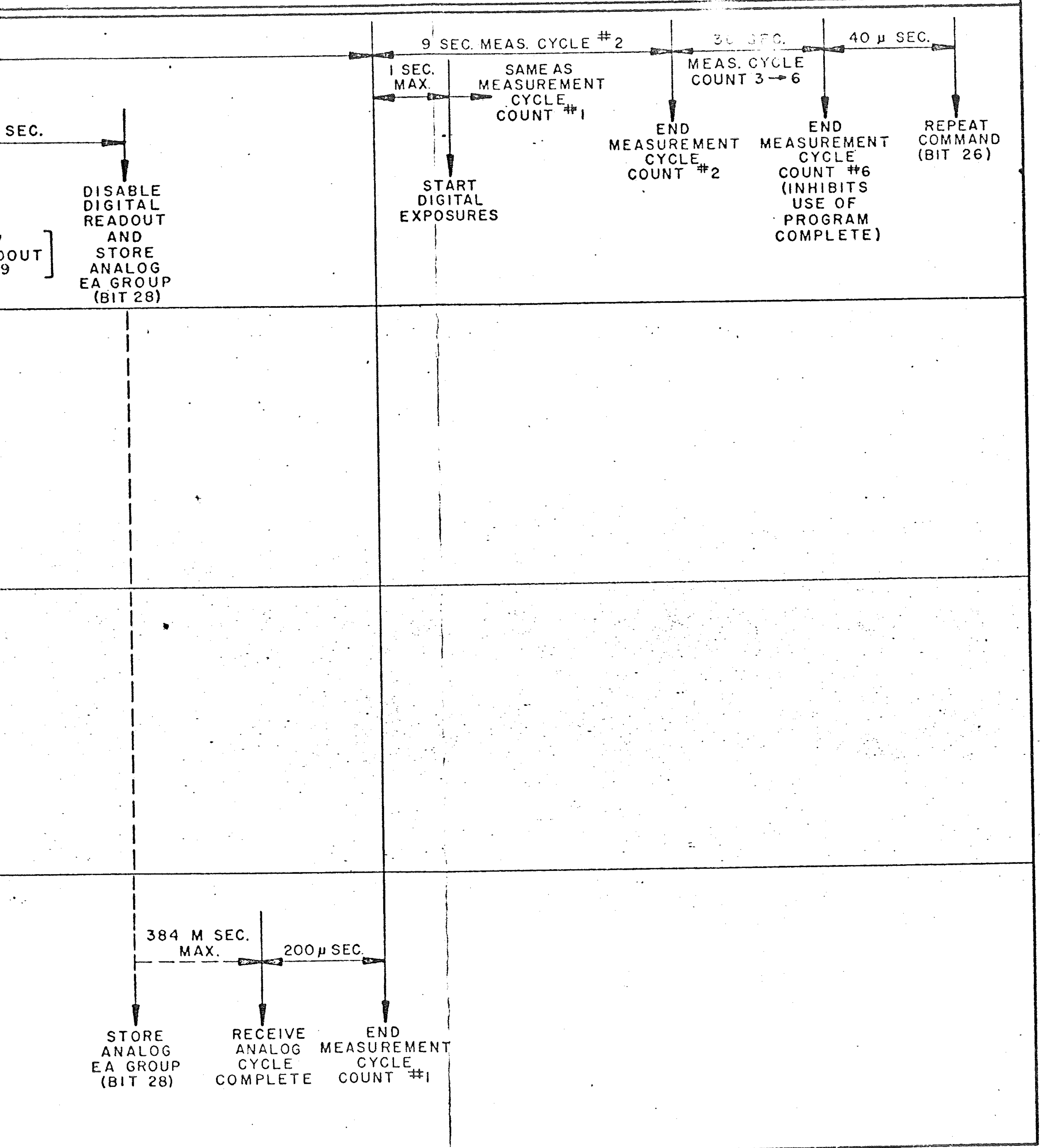


FIG. VII-9 TYPICAL OAO-WEP STORED COMMAND TI

XECUTION TIME



ED COMMAND TIMING

SAMPLE, SINGLE OBSERVATION PAGE 2

U. W. COMMAND LINE 1 TIME < 2 MIN.

COMMAND	1	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0
BIT No	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

WORD No																										
1-64	SPACECRAFT STATUS FRAME																									
65-66	PROGRAM CODE WORDS																									
	BIT No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
67	EXPERIMENT	0	0	0	-	-	-	-	-	-	-	-	1	0	1	1	0	1	0	0	N	O	CH	A	NG	E
68	DIGITAL	0	0	1	-	-	-	-	-	-	-	-	1	0	1	0	1	1	-	-	-	-	-	-	-	-
69	(ED) DATA	0	1	0	-	-	-	-	-	-	-	-	1	0	1	0	1	1	-	-	-	-	-	-	-	-
70	FRAME		1	1	-	-	-	-	-	-	-	-	1	0	1	1	0	1	N	O	C	H	A	N	G	E
71-75	ANALOG DATA SET																									
76		0	0	0	-	-	-	-	-	-	-	-														
77	SAME AS	0	0	1	-	-	-	-	-	-	-	-							-	-	-	-	-	-	-	-
78	ED ABOVE	0	1	0	-	-	-	-	-	-	-	-							-	-	-	-	-	-	-	-
79			1	1	-	-	-	-	-	-	-	-														
80-84	ANALOG DATA SET																									
85		0	0	0	-	-	-	-	-	-	-	-														
86	SAME AS	0	0	1	-	-	-	-	-	-	-	-							-	-	-	-	-	-	-	-
87	ED ABOVE	0	1	0	-	-	-	-	-	-	-	-							-	-	-	-	-	-	-	-
88			1	1	-	-	-	-	-	-	-	-														
89-93	ANALOG DATA SET																									
94		0	0	0	-	-	-	-	-	-	-	-														
95	SAME AS	0	0	1	-	-	-	-	-	-	-	-							-	-	-	-	-	-	-	-
96	ED ABOVE	0	1	0	-	-	-	-	-	-	-	-							-	-	-	-	-	-	-	-
97			1	1	-	-	-	-	-	-	-	-														
98-102	ANALOG DATA SET																									
103		0	0	0	-	-	-	-	-	-	-	-														
104	SAME AS	0	0	1	-	-	-	-	-	-	-	-							-	-	-	-	-	-	-	-
105	ED ABOVE	0	1	0	-	-	-	-	-	-	-	-							-	-	-	-	-	-	-	-
106			1	1	-	-	-	-	-	-	-	-														
107-111	ANALOG DATA SET																									
112		0	0	0	-	-	-	-	-	-	-	-														
113	SAME AS	0	0	1	-	-	-	-	-	-	-	-							-	-	-	-	-	-	-	-
114	ED ABOVE	0	1	0	-	-	-	-	-	-	-	-							-	-	-	-	-	-	-	-
115			1	1	-	-	-	-	-	-	-	-														
116-120	ANALOG DATA SET																									
121-184	SPACECRAFT STATUS FRAME																									

TOTAL TIME IN SPACECRAFT MINUTES TO GENERATE ALL DATA ______

U. W. LINE	1	2	3	4	5	6	7	8	9	10	11	12	13
GAEC LINE No	7	26	11	8	25	12	10	23	9	24	28	29	27
OCTAL GAEC LINE No	06	31	12	07	30	13	11	26	10	27	33	34	32

ALL BLANK COLUMNS = DON'T CARE

---------------- = DIGITAL DATA

PREPARED BY C.B. DATE ______

COMMAND MODE A NON-CYCLIC, PH1 E3 F2, PH2 E2 F2, PH3 E2 F2, PH4 E3 F2

FIG. VII - 10

SAMPLE, SINGLE OBSERVATION PAGE 3

U. W. COMMAND LINE 9 TIME <15 MIN

BIT No	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
COMMAND	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	1

	WORD No		1	2	3	4–11	12–17	18	19	20	21	22	23	24	25
	1-64	SPACECRAFT STATUS FRAME													
	65-66	PROGRAM CODE WORDS													
		BIT No	1	2	3	4–11	12–17	18	19	20	21	22	23	24	25
~25 SETS OF THESE WORDS	67	EXPERIMENT DIGITAL (ED) DATA FRAME	0	0	0	--------		1	0		NO CHANGE				
	68		0	0	1	--------	NO CHANGE	-	-	-	-	-	-	-	-
	69		0	1	0	--------		-	-	-	-	-	-	-	-
	70		0	1	1	--------		1	1	1	1	0	0	0	1
	71-75	ANALOG DATA SET													
~25 SETS OF THESE WORDS	76	SAME AS ED ABOVE EXCEPT	0	0	0	--------									
	77		0	0	1	--------		-	-	-	-	-	-	-	-
	78		0	1	0	--------		-	-	-	-	-	-	-	-
	79			1	1	--------						1	0		
	80-84	ANALOG DATA SET													
~25 SETS OF THESE WORDS	85	SAME AS ED ABOVE EXCEPT	0	0	0	--------									
	86		0	0	1	--------		-	-	-	-	-	-	-	-
	87		0	1	0	--------		-	-	-	-	-	-	-	-
	88			1	1	--------						1	1		
	89-93	ANALOG DATA SET													
~25 SETS OF THESE WORDS	94	SAME AS ED ABOVE EXCEPT	0	0	0	--------									
	95		0	0	1	--------		-	-	-	-	-	-	-	-
	96		0	1	0	--------		-	-	-	-	-	-	-	-
	97			1	1	--------						0	1		
	98-102	ANALOG DATA SET													
FROM 0 TO 7 SETS OF THESE WORDS	103	ED DATA FRAME	0	0	0	--------		0	0		NO CHANGE				
	104		0	0	1	--------	NO CHANGE	-	-	-	-	-	-	-	-
	105		0	1	0	--------		-	-	-	-	-	-	-	-
	106			1	1	--------		1	1	1	1	0	1	0	1
	107-111	ANALOG DATA SET													
NOT USED	112		0	0	0	--------									
	113		0	0	1	--------		-	-	-	-	-	-	-	-
	114		0	1	0	--------		-	-	-	-	-	-	-	-
	115			1	1	--------									
	116-120	ANALOG DATA SET													
	121-184	SPACECRAFT STATUS FRAME													

TOTAL TIME IN SPACECRAFT MINUTES TO GENERATE ALL DATA

U. W. LINE	1	2	3	4	5	6	7	8	9	10	11	12	13
GAEC LINE No	7	26	11	8	25	12	10	23	9	24	28	29	27
OCTAL GAEC LINE No	06	31	12	07	30	13	11	26	10	27	33	34	32

ALL BLANK COLUMNS = DON'T CARE -------------- = DIGITAL DATA

PREPARED BY ______ DATE ______

COMMAND MODE C, S.S #2, E1, REVERSE, TO END OF TRAVEL

FIG. VIII - 11